Invasive Species Strategic Management Plan For Seattle's Major Watersheds: Cedar, Tolt, and Lake Youngs

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Executive Summary

Invasive species are non-native species that pose significant risks to native biodiversity, fish and wildlife habitat, and in many cases, basic ecological functioning. The Invasive Species Program for Seattle's three major watersheds fulfills several legal and policy requirements to eradicate (all plants must be completely eliminated) or control (no reproduction or spread of plants allowed) invasive species.

The Program, initiated in 2007, has three main components:

1. Terrestrial plants and animals
2. Aquatic plants and animals
3. Insects and pathogens

Program goals include maintaining municipal water quality and maintaining or restoring native biodiversity, habitat, and natural ecological functions.

Specific Program objectives are to

- Prevent introduction of invasive species whenever possible.
- Minimize human-caused dispersal and spread of invasive species.
- Help educate people working in or using the watersheds about the adverse impacts of invasive species and enlist their help, as possible, in preventing introduction or spread of invasive species.
- Minimize human-caused ground disturbance that facilitates invasive species introduction and spread.
- Find and treat new infestations while they are small enough to eradicate in a cost-effective manner before they cause significant ecological damage (an approach termed Early Detection/Rapid Response that has been proven worldwide to be the most cost-effective way to deal with invasive species).
- Use the most cost-effective, efficacious treatments with the least adverse environmental and social impact (using Integrated Vegetation Management principals).
- Eradicate certain target species that are legally required, have extremely limited distribution, or pose a highly significant ecological threat (eradication is more cost-effective over the long term than on-going control).
- Significantly reduce the existing number and size of infestations of targeted invasive species, especially in sensitive habitats, such that they can be easily and cost-effectively controlled.
- Restore native biodiversity and ecosystem functioning in key habitats to increase resistance to future invasions.
- Work collaboratively with local and state agencies and other land managers.

To date the primary focus has been on invasive plants. Extensive surveys are complete, with 48 terrestrial and two aquatic invasive plant species documented. An ecological risk analysis was completed for all 50 species, and varying levels of control have been initiated on 36 of them (maps and details of treatments are provided in Appendix I). Seattle Public Utilities (SPU) Water Quality Laboratory developed a draft document addressing prevention of aquatic nuisance species in Seattle water supply watersheds, with initial implementation in 2010. For forest insects and pathogens, the Forest Ecology Work Unit monitors annual reports from Washington Department of Natural Resources flights to document cause and extent of tree death, and investigates unusual occurrences for a possible outbreak.

The Invasive Species Program manager used information from local, state, and national experts, site-specific data, and consultation with SPU staff to develop a series of ecological management

recommendations to prevent, reduce, control, or eradicate invasive species from the watersheds. Most are already implemented (marked with asterisk), and should reduce Program costs over time. SPU managers will balance risks, benefits, and costs, and decide whether and how to implement the remainder of the recommendations.

- Prevent introduction and spread of invasive species by:
    - Maintaining the policy of no unsupervised public access to the watersheds*
    - Requiring decontamination and inspection of vehicles, equipment, and materials (e.g., pipe) used in the municipal water supply*
    - Limiting the use of vehicles driven outside the watersheds and washing vehicles (e.g., automatic tire and undercarriage washer) when entering the watersheds
    - Frequent washing of vehicles and equipment stationed within the watersheds*
    - Decreasing human-caused ground disturbance, including elevating brushing blades to a minimum of four to six inches of ground clearance, decreasing brushing frequency, and brushing only those areas where it is required for safety or project implementation*
    - Rapidly re-vegetating areas of human-caused ground disturbance*
    - Using only uncontaminated gravel and instituting a gravel tracking system
    - Limiting use of straw and using only certified weed-free straw*
    - Enhancing native biodiversity and forest health through various silvicultural techniques including creating canopy small gaps, snags, and logs, thinning, and planting*
- Qualified biologists conduct routine surveys to find and treat new infestations while they are small enough to eradicate in a cost-effective manner before they cause significant ecological damage (Early Detection/Rapid Response).*
- Program manager prioritize eradication and control of existing infestations among species by using legal requirements and ecological risk assessment. Prioritize within species using number, size, and location of patches.*
- Use Integrated Vegetation Management principles to determine the most cost-effective, efficacious treatments with the least adverse environmental and social impact.*
- Monitor treatments for effectiveness and change approaches when appropriate.*

To continue current levels of service, the Invasive Species Program needs the following components:

1. Program manager with scientific biological and botanical expertise to oversee and coordinate all projects, contracts, and budget, as well as conduct botanical surveys, collect and analyze data, and implement treatments
2. Staff or seasonal field technician with scientific botanical experience to conduct botanical surveys, collect data, and implement treatments
3. Regular ecology and operations staff to provide specific expertise and supplement field work during critical times of the growing season
4. Contract field crews to implement restoration projects and treatments requiring a large number of people within a short time frame during the growing season
5. Consultants providing specific expertise such as certified underwater divers with expertise in aquatic plant identification and removal

In order to continue to deal with the current levels of infestation and the on-going threat of new invasive species introductions into the watersheds, this needs to be an on-going program. However, we anticipate that the budget will decrease after approximately 2017, once management recommendations are

implemented, all initial surveys are complete, and current high numbers and levels of invasive species are decreased to levels that can be more cost-effectively controlled.

1.0 Background/Overview

The City of Seattle owns two major municipal watersheds on the western slopes of the Cascade Mountains, the Cedar River Municipal Watershed (Cedar) and the South Fork Tolt Municipal Watershed (Tolt). In addition, Seattle owns a reservoir and water treatment facility near Maple Valley, the Lake Youngs Reserve (Lake Youngs). These watersheds are managed by Seattle Public Utilities (SPU) to supply drinking water to over 1.3 million people. They encompass over 100,000 acres of mainly forested land, much of which was historically used for resource extraction, primarily timber harvest. Over 85% of the forest was logged and there were several logging and mining towns and camps in the Cedar, as well as farms at Lake Youngs. Since the City acquired much of the land in the 1900s, all areas have been closed to unsupervised public access. The watersheds are currently managed to provide a high quality drinking water supply, as well as restoration of fish and wildlife habitat, native biodiversity, forest health, and natural ecosystem functions.

Invasive species are non-native species that pose significant risks to native biodiversity, fish and wildlife habitat, and even basic ecological functioning, with some invasive plants and animals threatening water quality and supply. Globally, invasive species are considered the second greatest threat to endangered wildlife populations next to habitat loss. Global climate change is expected to further increase the risks posed by invasive plants and some animals, because changed disturbance regimes and higher carbon dioxide content in the atmosphere have been shown to favor many invasive over native species. In addition, changed environmental circumstances may create conditions where some native species of insects or pathogens have outbreaks that can kill massive areas of forest. Control and eradication of invasive species in the three major municipal watersheds is necessary not only to carry out the core utility function of protecting water quality and supply, but also to meet several legal and policy requirements.

The purpose of this document is to describe SPU's invasive species management program in its major watersheds by documenting the history and current status of invasive species management efforts, providing a summary of accomplishments, and establishing program goals and objectives, management strategies, and recommendations for the future.

1.1 Legal and Policy Requirements

1) **State and County Law**. In 2013 in King County, Washington State and King County law required 41 noxious weed species to be eradicated (Class A – all plants must be completed eliminated) and 51 species to be controlled (Class B and some Class C - no reproduction or spread of the plants allowed). An additional 46 species are recommended for control because of the ecological damage they can cause, but are currently so widespread that control is not legally required (termed "non-regulated noxious weeds" and "weeds of concern"). Of these listed species, one Class A, ten Class B, and 30 recommended control species are known to occur within one or more of the three watersheds. If a landowner does not comply with the laws to eradicate or control invasive species, King County has the legal authority to impose fines or file a Failure to Control Notice. The County can then come onto the landowner's property and control the species using whatever method they choose (including herbicide). They will then bill the landowner for their costs, which is usually much more expensive than if the landowner had initially controlled the invasive themselves.

2) **SPU Policy**. SPU's corporate environmental objectives state that SPU will "implement strategies and actions to achieve and exceed goals and expected outcomes of environmental laws" and will "lead on regional environmental issues, working cooperatively with other organizations to promote common environmental goals and objectives" (SPU Environmental Policy 2004). As such, SPU's control or eradication of certain invasive species found within Seattle's ownership, as required and recommended by Washington State and King County, is consistent with SPU's Environmental Policy.

3) **Cedar River Watershed Habitat Conservation Plan (HCP)**. The HCP does not directly address invasive species, but it does commit SPU to protect and restore habitat for federally listed species and enhance native biodiversity within the Cedar. Invasive species are one of the greatest current threats to biodiversity, and critical habitat for some fish and wildlife species listed in the HCP may be threatened by invasive species. To the extent that invasive species threaten native biodiversity or habitat for listed fish and wildlife species, invasive species control should be performed to support HCP goals.

1.2 Invasive Species Program Background

In January 2007, an Invasive Species Program Development Plan (PDP) for Seattle's three major municipal watersheds was approved and funded as a Capital Improvement Project. In February 2009 the Program was moved to Operations and Maintenance funding as a result of recommendations by an auditor.

As part of this initial PDP, several key objectives were fulfilled:

- The extent of the problem was determined by having qualified botanists conduct intensive surveys for non-native invasive plants.
- Literature was reviewed on effectiveness, risks, and costs of potential methods of eradication, control, and containment for key invasive species.
- Several experimental control methods for key invasive species were initiated.
- Reproduction and spread were controlled for all species legally required to control.
- An ecological risk analysis was completed for each invasive species found to be present in the watersheds.
- Recommendations were developed to minimize invasive species spread from operational practices such as road maintenance and improvement, and rights-of-way (ROW) management.
- A prioritization scheme was developed for deciding which species and locations should be controlled first.

A detailed summary of the plant surveys conducted and all the invasive plants eradication and control work accomplished to date is provided in Appendix 1.

1.3 Invasive Species Program Goals and Objectives

The primary goals of the Invasive Species Program are to:

1. Maintain municipal water quality.
2. Maintain or increase native biodiversity, restore habitat for native HCP-listed fish and wildlife species, and maintain and restore natural ecological functions.

Specific objectives are to:

- Prevent introduction of invasive species whenever possible.
- Minimize human-caused dispersal and spread of invasive species.

- Help educate people working in or using the watersheds about the adverse impacts of invasive species and enlist their help, as possible, in preventing introduction or spread of invasive species.
- Minimize human-caused ground disturbance that facilitates invasive species introduction and spread.
- Find and treat new infestations while they are small enough to eradicate in a cost-effective manner before they cause significant ecological damage (an approach termed Early Detection/Rapid Response).
- Use the most cost-effective, efficacious treatments with the least adverse environmental and social impact (using Integrated Vegetation Management principals).
- Eradicate certain target species that are legally required, have extremely limited distribution, or pose a highly significant ecological threat (more cost-effective than on-going control).
- Significantly reduce the existing number and size of infestations of targeted invasive species, especially in sensitive and limited habitats, to a point where they can be easily and cost-effectively controlled.
- Restore native biodiversity and ecosystem functioning in key habitats to increase resistance to future invasions.
- Work collaboratively and share data with local and state agencies, as well as other land managers.

2.0 Watershed Inventories for Invasive Species

It is essential to determine the extent of an invasive species problem before effective treatment strategies can be developed. Consequently, in 2007 and 2008 we had expert botanists conduct surveys in selected areas of the three municipal watersheds for 44 invasive terrestrial plant species legally required to control (Class A, B, and some C) and 11 plant species recommended for control. Surveys were concentrated in areas most likely to contain invasive plants, including areas of frequent disturbance such as roads, gravel pits, and riparian areas, as well as sensitive habitats such as wetlands and meadows. Survey protocol included slowly riding a bicycle along roads, and walking through other habitats. The botanists documented locations of all invasive plants on the target list with GPS and estimated the size of each located population. The botanists spent approximately 730 hours surveying the Cedar, 100 hours surveying the Tolt, and 70 hours surveying Lake Youngs.

SPU biology staff supplemented surveys for these target species, plus conducted surveys for numerous other invasive terrestrial plant species that pose significant risks but are not legally required for control. These surveys are ongoing as part of the Early Detection/Rapid Response protocol (Section 4.2). Presence of non-target invasive terrestrial plant species were noted, but many are not yet mapped. A total of 48 invasive terrestrial plant species were documented from all surveys (Table 1). Of these, 34 species have had at least some level of control. Areas surveyed and maps of the locations of each species in each watershed, along with all treatment conducted through 2013, are found in Appendix 1.

Surveys for invasive aquatic plants have been conducted in Walsh Lake and Rock Creek Wetland in the Cedar. Two aquatic invasive plant species (Eurasian milfoil and white water lily) were found in Walsh Lake and none in the wetland. Both are being controlled in Walsh Lake. The Lake Youngs reservoir is periodically surveyed for Eurasian milfoil, which was eradicated there in the 1990s, but it is not surveyed for other invasive aquatic plants.

Table 1. Non-native Invasive Plant Species in Seattle's Major Municipal Watersheds
(species listed alphabetically by scientific name within each management priority section)

SCIENTIFIC NAME	COMMON NAME	ECOLOGICAL RISK	KING COUNTY LISTING STATUS (2013)	WA STATE LISTING STATUS (2013)	WHERE LOCATED	DISTRIBUTION	GOAL
High Management Priority (Legally Required)							
Centaurea biebersteinii (maculosa)	Spotted knapweed	High	Class B	Class B	Cedar, Lake Youngs	Few locations	Eradicate
Hieracium aurantiacum	Orange hawkweed	High	Class B	Class B	Cedar, Lake Youngs	Scattered, mainly in lower elevations	Control spread, reduce size & number of patches
Hieracium caespitosum	Yellow (meadow) hawkweed	High	Class B	Class B	Cedar, Tolt	Widespread, mainly in upper elevations	Control spread, reduce size & number of patches
Hieracium piloselloides	Tall hawkweed	High	Class B	Class B	Cedar	2 known locations	Eradicate
Hieracium sabautum	European hawkweed	High	Class A	Class A	Cedar	4 known locations	Eradicate
Impatiens glandulifera	Policeman's helmet	High	Class B	Class B	Cedar	1 known location	Eradicate
Linaria dalmatica	Dalmatian toadflax	High	Class B	Class B	Cedar	2 known locations	Eradicate
Lythrum salicaria	Purple Loosestrife	High	Class B	Class B	Lake Youngs	1 known location	Eradicate
Potentilla recta	Sulfur cinquefoil	High	Class B	Class B	Cedar	2 known locations	Eradicate
Senecio jacobaea	Tansy ragwort	High	Class B	Class B	Cedar, Tolt, Lake Youngs	Widespread, mainly in lower elevations	Control spread, reduce size & number of patches
High Management Priority (Very High Ecological Threat)							
Myriophyllum spicatum	Eurasian water-milfoil	Very High	Non-regulated noxious weed	Class B	Cedar	1 known location (Walsh Lake)	Eradicate
Polygonum bohemicum	Bohemian knotweed	Very High	Class B within 200 feet of Cedar River	Class B	Cedar, Lake Youngs	About 20 acres total, mainly in lower Cedar. 1 location in Lake Youngs	Eradicate

High Management Priority (High Ecological Threat with Limited Distribution)							
Buddleia davidii	Butterfly-bush	High	Non-regulated noxious weed	Class B	Cedar, Tolt, Lake Youngs	Few locations	Eradicate
Clematis vitalba	Old man's beard	High	Non-regulated noxious weed	Class C	Cedar	1 known location	Eradicate
Hedera helix	English ivy	High	Non-regulated noxious weed	Class C	Cedar, Lake Youngs	Several locations	Eradicate all in Lake Youngs; Eradicate all small patches in Cedar
Iris pseudacorus	Yellow flag iris	High	Non-regulated noxious weed	Class C	Cedar	1 known location	Eradicate
Lamiastrum galeobdolon	Yellow archangel	High	Non-regulated noxious weed	Class B	Cedar	2 known locations	Eradicate within forest. Prevent spread from neighboring property
Nymphaea odorata	White water lily	High	Non-regulated noxious weed	Class C	Cedar	1 known location (Walsh Lake)	Eradicate
Prunus laurocerasus	English laurel	High	Weed of concern		Lake Youngs	3 known locations	Eradicate
Rosa multiflora	Multifloral rose	High	Weed of concern		Cedar	2 possible locations	Eradicate if present
Medium Management Priority (High Ecological Threat, Generally Already Widespread)							
Cirsium arvense	Canada thistle	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread	Eradicate key patches
Cirsium vulgare	Bull thistle	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread	Eradicate key patches
Convolvulus arvensis	Field Bindweed	High	Non-regulated Noxious weed	Class C	Cedar, Tolt	Concentrated around Cedar Falls Compound	Eradicate key patches. Control small and new infestations
Cytisus scoparius	Scots broom	High	Non-regulated noxious weed	Class B	Cedar, Tolt, Lake Youngs	Widespread	Eradicate key patches

Dipsacus fullonum	Fuller's (common) teasel	High	Non-regulated noxious weed	Class C	Cedar	1 known location	Eradicate
Hieracium lachenalii	Common hawkweed	High	Class B	Class C	Cedar, Tolt	Widespread, mainly in upper elevations	Control key patches
Ilex aquifolium	English holly	High	Weed of concern		Cedar, Lake Youngs	Widespread	Eradicate key patches
Rubus armeniacus	Himalayan blackberry	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread, especially in wetlands, riparian areas	Eradicate key patches
Rubus laciniatus	Evergreen (cutleaf) Blackberry	High	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread, especially in wetlands, riparian areas	Eradicate key patches
Solanum dulcamara	Bittersweet nightshade	High	Weed of concern	Proposed Class C addition	Cedar	Large matting patches in wetlands	Eradicate key patches
Tanacetum vulgare	Common tansy	High	Non-regulated noxious weed	Class C	Cedar, Lake Youngs	Widespread in lower elevations	Eradicate or Control key patches
Verbascum thapsus	Common mullein	High			Cedar, Tolt	Widespread	Eradicate or Control key patches
Low Management Priority (Lower Current Ecological Threat, Generally Already Widespread)							
Acer pseudoplatanus	Sycamore maple	Moderate or Low			Cedar	Uncommon. Planted at Cedar Falls Compound	Eliminate major seed sources. Monitor
Arctium lappa	Greater Burdock	Moderate or Low			Cedar	Increasing numbers in lower elevations	Control key patches
Cotoneaster horizontalis	Cotoneaster	Moderate or Low			Cedar	Several locations	Control key patches
Crataegus monogyna	Common hawthorn	Moderate or Low	Weed of concern		Lake Youngs	Scattered, mainly in large wetland	
Digitalis purpurea	Foxglove	Moderate or Low			Cedar, Tolt, Lake Youngs	Widespread & spreading rapidly	Control key patches
Geranium robertianum	Herb-robert	Moderate or Low	Non-regulated noxious weed	Class B	Cedar	Widespread	
Hypericum perforatum	Common Saint Johnswort	Moderate or Low	Non-regulated noxious weed	Class C	Cedar, Tolt	Widespread	Monitor results of biocontrol experiment

Hypochaeris radicata	Common catsear	Moderate or Low	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Widespread	
Impatiens capensis	Spotted jewelweed	Moderate or Low	Weed of concern	Proposed Class C addition	Cedar	Widespread in wetlands, riparian areas	Monitor key patches
Leucanthemum vulgare	Oxeye Daisy	Moderate or Low	Non-regulated noxious weed	Class B	Cedar, Tolt	Widespread in high elevations	
Linaria vulgare	Yellow toadflax (butter and eggs)	Moderate or Low	Non-regulated noxious weed	Class C	Cedar	Widespread in low elevations	
Phalaris arundinacea	Reed canarygrass	Moderate	Non-regulated noxious weed	Class C	Cedar, Tolt, Lake Youngs	Common in some wetlands	
Ranunculus repens	Creeping buttercup	Moderate or Low	Weed of concern		Cedar	Widespread, especially in wetlands	
Robinia pseudoacacia	Black locust	High			Cedar	1 known location	Eradicate as part of restoration project
Senecio vulgaris	Common groundsel	Moderate or Low	Non-regulated noxious weed	Class C	Cedar, Tolt	Widespread	
Sorbus aucuparia	European mountain-ash	Moderate or Low	Weed of concern		Cedar	Seen near Cedar Falls Compound	Monitor
Taraxacum officinale	Dandelion	Moderate or Low			Cedar, Tolt. Lake Youngs	Widespread	

Chester Morse Lake (Cedar) had limited plant surveys conducted on both emergent and submerged sections of the Cedar River delta, Youngs Cove, and selected portions of the Masonry Pool in 1989, 1996, and 2007. Although these surveys targeted native plants, no invasive species were noted. Within the Cedar, Rock Creek Wetland and the 14 Lakes complex of small ponds were surveyed for aquatic invasive plants species in 2008 and 2010 respectively, with none found. The Tolt Reservoir has not been surveyed for invasive aquatic plants, but poses low risk because of the high elevation and generally steep rocky sides. Smaller lakes, wetlands, and streams have not yet been surveyed.

Specific surveys have not yet been conducted for invasive aquatic or terrestrial animals, insects, or pathogens. However, Washington Department of Natural Resources conducts annual flights to document cause and extent of tree death, which include both non-native and native causes. The Forest Ecology Work Unit monitors these annual reports, and any unusual occurrences of non-native species will be investigated. If large outbreaks of native insects or pathogens should occur, these will also be investigated.

3.0 Invasive Species Program Components and Responsibilities

The Invasive Species Program consists of three main components: terrestrial plants and animals, aquatic plants and animals, and insects and pathogens.

3.1 Terrestrial Plants and Animals.

Survey and control of invasive terrestrial plants and animals is the responsibility of the Invasive Species Program manager. To date the Program has focused primarily on survey and control of invasive terrestrial plants because of the large number and generally wide distribution already present in the watersheds. Surveys for non-native invasive terrestrial animals will occur as it becomes necessary.

3.2 Aquatic Plants and Animals.

Because of the significant threat posed by invasive aquatic plants and animals to water quality and supply, the SPU Water Quality Laboratory (WQL) is responsible for survey and control of aquatic plants and animals in Chester Morse Lake and the Masonry Pool (Cedar), the Tolt Reservoir, the Tolt Regulating Basin, and the Lake Youngs reservoir. Key WQL and SPU Protection staff have been formally trained in detection of Aquatic Nuisance Species (ANS). Because of the extremely high risk to the municipal water supply from species such as quagga and zebra mussels, a detailed plan for prevention of ANS in Seattle's water supply watersheds has been developed by the WQL. This plan details specific decontamination procedures required by anyone working in the water supply, with initial implementation starting in 2010. The Invasive Species Program is responsible for survey and control of aquatic plants and animals found in all other small lakes, streams, and wetlands, as well as communication and coordination of these activities with the WQL. A list of aquatic plants and animals that could potentially infest the watersheds is found in Appendix 2.

3.3 Insects and Pathogens.

The Forest Ecology Work Unit, Watershed Services Division, is responsible for survey and response to invasive insects and tree pathogens in the watersheds. The primary threat currently is from non-native species. Native insects and pathogens have evolved with the forest and generally provide small to intermediate levels of disturbance that increase forest structural diversity and facilitate greater native biodiversity. However, some native insects and pathogens could potentially have major outbreaks as a result of a change in the forest, as might be seen with climate change or after a major fire. In-house monitoring has been conducted for the native Douglas-fir beetle in target areas, but more species may need to be monitored in the future. A list of both non-native and native forest insects and pathogens that could potentially adversely impact the watershed forests is found in Appendix 3 and maps of tree death in the Cedar by causal agent (species of insect or pathogen) in Appendix 4. The Invasive Species Program manager is responsible for communication and coordination with Forest Ecology, as well as supplying support when requested.

4.0 Management Strategies and Recommendations

The Invasive Species Program is incorporating several key strategies and recommendations widely used at the local, state, national, and international levels. The following recommendations were developed using over four years of site-specific data and in consultation with Watershed Ecosystems and Operations Section personnel. These are ecological recommendations only, and do not consider ease or cost of implementation, or other factors. Most of the recommendations are already, or soon will be, implemented in the Cedar as part of normal operating procedures or the Invasive Species Program. SPU managers will assess the trade-offs of risk of invasion with difficulty and cost of implementing the remaining recommendations. They will then decide whether and how to apply these recommendations, and may develop policies and procedures as they see fit.

4.1 Prevent Introduction of New, and Spread of Existing Infestations.

The easiest and most cost-effective strategy concerning invasive species is to prevent their occurrence in the first place. Preventing spread of existing infestations is legally required for several species and is the most cost-effective way to deal with all existing infestations. Methods we recommend to prevent introductions and spread of invasive species in the watersheds include:

- **Maintain the existing policy of no unsupervised public access in the watersheds**. This is the most essential strategy, as it has been demonstrated innumerable times that the public is the most common vector for invasive species introduction and spread, especially for terrestrial plants and aquatic plants and animals. Vectors include their vehicles, clothing, shoes, equipment, pets, etc.
- **Require decontamination and inspection of vehicles and equipment used in the water bodies.** Preventing ANS from entering the water supply system is critically important because of the risk to both water quality and supply, and the extreme cost of control if certain ANS are introduced. Detailed decontamination requirements for ANS are presented in the Prevention of Aquatic Nuisance Species in Seattle Water Supply Watersheds document. Initial implementation began in 2010.
- **Limit the use of vehicles that have been driven outside the watersheds from using roads within the watershed and clean vehicles when entering the watersheds**. The most common vector for dispersal of invasive plants is seeds or other plant propagules caught in tires, wheels, or undercarriages of vehicles and trailers.
    - SPU Watersheds Staff. Watersheds staff use City vehicles and heavy equipment that are rarely driven outside the watershed, which minimizes the risk of new introductions. However, when City vehicles are driven outside the watershed, especially through areas of known infestation, we recommend that the vehicle is washed thoroughly upon re-entering the watershed, paying particular attention to the tires and undercarriage. This can easily be accomplished for the Cedar at the drive-through tire and undercarriage washer or the wash station both located near the main entrance at Cedar Falls.
    - State and federal agency staff, contractors, researchers, tribal members, and others. Most non-SPU staff currently use their own vehicles and usually do not wash their vehicle upon entering the watersheds. This happens most often in the Cedar, where the most non-staff use of a watershed occurs. Many of these vehicles are driven through infestations on forest roads in other ownerships. To reduce this risk, we recommend that vehicles entering the watershed at Cedar Falls use the drive-through wheel washer prior to driving further into the watershed. This requirement could be made a part of future contracts and access agreements.
- **Frequent washing of vehicles and equipment stationed within the watersheds**. The best way to prevent infestation spread via vehicles and equipment is frequent washing. It is especially important to wash equipment when it moves out of an area known to be contaminated. It is also important to wash vehicles after they have been used in one area of the watershed before moving into another (e.g., lower to upper watershed). This is particularly important if vehicles are driven on roads that have not been brushed recently (increasing the risk of seeds or other plant parts catching in the undercarriage), as is frequently necessary for staff surveying for invasive species and Protection staff. This is easily facilitated with the tire and undercarriage washing station at Cedar Falls.
- **Decrease human-caused disturbance.** Most invasive plant species flourish in areas of ground disturbance. Minimizing human-caused disturbance will decrease the likelihood that a new species will invade or existing species will spread. Methods to do this are already being implemented along roads in the Cedar by Operation staff. They include:

- Elevating brushing blades along roads and in ROWs such that at least four to six inches of vegetation remain (more if the native vegetation is low-growing). This will limit ground disturbance and allow existing native vegetation to better outcompete invasive species.
- Decreasing brushing frequency along roads and in ROWs so native vegetation has adequate time to recover and out-compete potential invasive species.
- Brushing only those areas required, for example, brush only where native vegetation has grown to a height where it causes a safety issue or interferes with work. Not brushing areas of sword fern and low-growing salal can both save money in time and labor and discourage or prevent invasive species.

- **Rapidly re-vegetate areas of human-caused ground disturbance.** The most common instance when this will occur is during road decommissioning and other required road and bridge work. In accessible areas re-vegetation can be easily completed (and is already being implemented) with the hydro-seeder currently stationed at Cedar Falls. In addition, areas of known plant infestations on roads scheduled for decommissioning should be targeted for planting with native trees and shrubs that will eventually shade out most invasive species (also being implemented in the Cedar as funding allows). The Invasive Species Program coordinates with the Operations Section and HCP Planting Program on these projects.
- **Use only uncontaminated gravel and institute a gravel tracking system**. Contaminated gravel is a very common way that invasive plants are introduced and spread. The best way to minimize this risk is to ensure that invasive plants are controlled in on-site gravel pits and that any gravel purchased from off site is weed free. Instituting a gravel tracking system that includes the source of the gravel and where it is used would aid in identifying contaminated gravel sources. The Invasive Species Program has coordinated with the Operations Section in the Cedar to initiate this system by adding a quick and simple note in the Maximo program already used to track all road-related projects.
- **Limit use of straw; Use only certified weed-free straw**. Contaminated straw is another common source for invasive plants. Limiting the use of straw to allow more rapid growth of native plants and only using certified weed-free straw will help minimize the risk of bringing in new invasive species (often from eastern Washington). Cedar Operations has already greatly reduced their use of straw on decommissioned roads, using it only in specific areas as needed for erosion control, and already uses only certified weed-free straw.
- **Enhance native biodiversity in habitats that are at risk of invasion**. A healthy diverse habitat is often more resistant to invasion by non-native species than an area dominated by only one or two plant species. Projects enhancing native biodiversity are being implemented in the Cedar as part of the HCP and in the Tolt under the Tolt Management Plan. They include thinning, creating small canopy gaps, and planting native species. Projects at Lake Youngs are conducted as funding and staff are available. The Invasive Species Program contributes to this effort by removing invasive species in restoration sites and coordinating with HCP and Tolt restoration programs.
- **Enhance forest health and resilience.** A healthy forest will be much more resistant to infestation by insects and pathogens than one that consists of trees stressed by low levels of water, nutrients, or light. Projects that will increase forest health are being implemented in the Cedar as part of the HCP and in the Tolt under the Tolt Management Plan and include thinning, creating small canopy gaps, and planting a variety of native trees and shrubs. Projects at Lake Youngs are conducted as funding and staff are available.

4.2 Early Detection/Rapid Response.

Early Detection/Rapid Response (EDRR) is a strategy that involves routine monitoring for a large number of invasive species. If a new infestation is found, it is rapidly treated while it is still small enough to eradicate in a cost-effective manner and before it has a chance to spread and cause significant ecological damage. This strategy has been proven world-wide to be the most cost-effective way to deal with invasive species.

EDRR in the three watersheds focuses primarily on terrestrial plants and consists of botanical surveys conducted by qualified biologists. Surveys target both new invasive species that potentially could invade but have not yet been documented and species known to be present in the watershed. Particular attention is paid to species that have been found in areas adjacent to the watershed (maps available from the King County Noxious Weeds Program). EDRR is implemented annually in the watershed to varying degrees, depending on staffing and funding

Not every area of each watershed needs to be surveyed for invasive species. For insects and pathogens, only some of the areas of tree death identified during flights (e.g., those identified as caused by non-native species) need to be targeted. For Aquatic Nuisance Species only those aquatic areas that can support the high-risk species that pose significant threats to the water supply need to be surveyed frequently. High priority areas for invasive plants, including those at high risk due to frequent disturbance and sensitive habitats such as wetlands, have already been identified (see Appendix 1, maps of areas surveyed for invasive plants in each watershed). For plants, we use a survey strategy based on risk of invasion.

- Very high risk areas because of frequent disturbance (e.g., heavily used roads and gravel pits) are surveyed annually or semi-annually.
- Areas that are disturbed less frequently (e.g., roads that are graded and brushed every two or three years, areas of episodic natural disturbance from flood or windthrow, recently decommissioned roads, restoration sites) are surveyed approximately one year after the disturbance, then periodically on a site-specific basis, depending on initial survey results and amount of disturbance.
- Sensitive habitats with low disturbance rates (e.g., certain wetlands, meadows) are surveyed using a rotating panel method, in which a limited number of habitats are surveyed each year, rotating through all the sites such that each is surveyed once every four or five years.

4.3 Eradication and Control of Existing Infestations.

Because there is a large number of invasive plant species already present in the watersheds, it is critical to have eradication and control strategies to deal with them. Work on each species and patch location needs to be prioritized such that the species and patches posing the greatest ecological risk are treated first (see prioritization guidelines in Section 5). Once species and locations are prioritized, then the most efficacious and cost-effective treatment method needs to be determined. The guidelines to determine methods are detailed in Section 6. Generally the most cost-effective method is to eradicate small patches and control larger ones. For occurrences of non-native insects, such as the Balsam woolly adelgid, areas of infestation need to be located and populations monitored. Then thresholds for treatment and types of treatment need to be determined.

4.4 Habitat Restoration.

Areas where invasive plant species have been eradicated or controlled are being restored to a diverse native vegetation community. An evaluation of the reasons for the initial successful invasion is conducted and site-specific conditions are altered, if possible, to decrease the likelihood of future re-invasion or invasions by other species. This usually consists of restoring the site with an appropriate

array of healthy native species, as biodiverse areas are generally more resistant to invasion than areas with few species or unhealthy plants.

If there is high potential that an appropriate diversity of native plants will colonize the restoration site naturally, then the site is simply monitored. If the site is not recolonized within a reasonable period of time (e.g., two growing seasons), or if it appears that there are insufficient native seed sources nearby, then a planting project is instigated. This is usually accomplished by coordinating with the HCP Planting Program in the Cedar and SPU staff with expertise in native plants and plant ecology.

5.0 Prioritization Guidelines

The following prioritization guidelines are used to determine 1) which plant species are the highest priority to treat and 2) within each plant species, which patches are the highest priority for treatment. Although these prioritization guidelines were developed for plant species already present in the watersheds, they could also be applied to forest insects and pathogens, and Aquatic Nuisance Species, as necessary.

Prioritization among species:

- Is the species legally required for eradication or control?
    - All species required to be eradicated or controlled are high management priority because Washington State and King County has already determined that these species pose a high ecological risk and are still present in small enough numbers regionally that they can effectively be controlled.
- If the species is not legally required for eradication or control, what is the level of ecological risk posed by the species?
    - Evaluate the degree of invasiveness; ability to outcompete natives; rate of potential spread; type of habitats the species occupies; and ecological impact of the species on native species, ecological processes, and ecological functions.
        - If the ecological risk of the species is determined to be very high, then that species is a high management priority for treatment.
        - If the ecological risk is high and there are limited locations within the watershed, then that species is a high management priority for treatment.
        - If the ecological risk is high, but the species is already widespread, it is moderate priority for treatment.
        - If the ecological risk is currently considered to be low, then the species will get a low priority for treatment. See Table 1 for list of invasive plant species present in the watersheds sorted by management priority.

Prioritization of locations to treat for species with high or moderate management priority:

- How many patches are there?
    - One or very few patches - attempt eradication unless there is no allowed treatment that is efficacious or it is very cost-prohibitive.
    - If there are many patches, prioritize treatment among patches based on a combination of patch location and size (see below).
- Where are the patches located? High priority locations are:

    - In or near sensitive or rare habitats, including wetlands, riparian areas (especially immediately adjacent to streams or ponds), meadows, and old-growth forest.
    - Along well traveled roads that pose a significant risk of spread.
    - In or near frequently disturbed and used areas (e.g., gravel pits) that pose a significant risk of spread.
    - Restoration sites where ground disturbance poses a significant risk of spread.
- How big are the patches?
    - Small patches are higher priority for early treatment because there is a greater chance of eradication, it takes less time and resources to treat, and it eliminates scattered patches as sources for new infestations.

6.0 Treatment Options for Invasive Plants

Integrated Vegetation Management (IVM) is an integrated, ecological approach to invasive plant species treatment. It relies on comprehensive information about the invasive species life cycle and its interaction with the environment, in combination with all potential control methods, to design the most effective combination of treatments to eradicate or control each species. We use this integrated approach for each species and site when determining the most efficacious and cost-effective treatment methods.

Each site is examined and an evaluation made as to what ecological condition made it favorable for the initial invasive species establishment and spread. If that condition can be changed (e.g., decreasing human-caused disturbance, planting native species), it is incorporated in the treatment plan. However, in most situations simply changing the ecological conditions is insufficient to control or eradicate the existing infestation. Consequently, a determination must then be made as to which treatment(s) will be effective on that particular site. Species, location, and size of patch are all significant variables considered.

Eradication and control treatment options we consider include:

- Mechanical removal, including hand pulling, cutting, or grubbing out roots, and excavating the roots by machine.
- Starving the roots by shading, generally using geotextile fabric.
- Biocontrols, if available and approved by the USDA Animal and Plant Health Inspection Service (APHIS). These are generally insects that target only the invasive plant species and no native species. It can take several years to build their populations to a point where they significantly influence the infestation, and they generally require a large concentrated population of the invasive plant.
- Herbicides are prohibited in the Cedar by Seattle City Council ordinance, with the current exception of a three-year window (2013-2016) in which knotweed may be treated with Imazapyr (see knotweed section in Appendix 1). They are allowed within the Tolt and Lake Youngs, however, and are considered on a case by case basis.

The treatment(s) with the least environmental impact are chosen unless they are not effective or are logistically impossible. Then the combination of treatments that are both effective and have the least adverse environmental impact are chosen. If treatments are equally effective with the same adverse environmental impact, then the least expensive option is chosen.

Most patches will take several consecutive years of treatment before they are reduced significantly, because of the extreme difficulty in removing all root and stem fragments, or a large seed bank in the soil. Repeated treatments will often create ground disturbance, which increases the likelihood that the site will be invaded or re-infested. It is important to re-vegetate the soil as soon as possible. However, it may not be appropriate to immediately plant the native species that will ultimately occupy the site (often trees and shrubs). If these species are planted throughout the site too soon, they can interfere with future control treatments, making it much more difficult and expensive to extract the invasive species. In addition, planting too early often results in higher mortality of the native plants because of the disturbance to their roots from future grubbing of the invasive species. A good option is to seed the disturbed area to grasses and forbs during the first few years of treatment, perhaps planting native trees and shrubs around the edges of the patch. Then, as the infestation is greatly reduced, native trees and shrubs can be safely planted throughout the site.

If the site is an area that is chronically disturbed and cannot be re-vegetated (e.g., active gravel pit), then an on-going control plan for the invasive species needs to be implemented.

7.0 Monitoring and Adaptive Management

Because treating invasive species (plants, insects, pathogens, and aquatic nuisance species) is virtually always a multi-year effort, it is critically important to monitor active treatment sites. Assuming a treatment was successful without verification often results in the few remaining individuals quickly re-colonizing the site, thus wasting all previous efforts at control. The frequency of monitoring will be both species and site-specific.

It is also important to keep detailed and accurate records of the results of every treatment and site visit. Because of the extreme variability between sites, research results in the literature may not always apply to each location. These site-specific datasets allow managers to determine the effectiveness of each treatment at each site, and whether future changes should be implemented. Only by having these long-term datasets can the most effective treatment with the least adverse environmental impact be determined and appropriate management changes made.

Invasive Species Program staff have found it is most cost-effective to combine invasive plant site monitoring with treatment because of the often long travel distances involved in reaching sites. That is, active treatment sites are visited, and if any invasive plant growth is observed, it is treated immediately before it has a chance to grow or reproduce. Of course, this applies only to those sites that can easily and efficiently be treated by a single person. We record detailed notes each time a treatment site is visited. Records include the date and staff person who conducted the monitoring and treatment, whether there were any invasive plants present, number and growth stage of plants, area covered by the plants, and type and amount of any treatment applied. These extensive records are maintained for each separate patch of each species and are used by the Program manager to determine future treatments and estimate work load and resource needs.

8.0 Invasive Species Program On-going Needs

The following recommendations are based on seven years of program development, extensive field experience in surveying and implementing a wide variety of treatments, and collecting and analyzing many years of data. This level of support will fulfill legal obligations and SPU policy requirements for the municipal watersheds and maintain the level of service provided since 2007.

- **Program Manager**. This person must have extensive scientific background, strong botanical skills, experience in restoration ecology, and excellent writing and communication skills. They oversee and coordinate all projects; manage the budget; develop, oversee, and implement contracts; supervise field staff and contractors; collect and analyze data; design new treatments and make treatment decisions; make management recommendations; manage the databases; create GIS maps; conduct surveys and monitoring, and implement treatments.
- **Staff or temporary field technician** with good botanical, scientific data collection, and computer software skills (4-6 months, full time annually during the field season). This person conducts surveys (Early Detection/Rapid Response), maps infestations using GPS, collects and records monitoring data, implements treatments on invasive species patches throughout the three watersheds, and helps coordinate field crews.
- **SPU Watershed Services Ecology and Operations staff**. These people supplement field work as needed during critical times or provide greater expertise than the field technician and field crews (e.g., GIS expertise). They conduct surveys, collect monitoring data, implement treatments, manage databases, and provide GIS assistance and support.
- **Contract field crews**. Implement habitat restoration projects or invasive species treatments that require a crew because a large area must be treated during a very short time frame.
- **Consultants**. Companies providing expertise not otherwise available in SPU, such as certified underwater divers with expertise in identifying all native and non-native aquatic plants and animals, certified herbicide applicators, and laboratories conducting specific water quality tests, used on an as-needed basis.
- **Basic supplies, equipment, miscellaneous**. This includes such supplies as geotextile fabric, tools, radios, waders, sprayers, herbicides, etc.

9.0 Invasive Species Program Future Projections

After several years of intensive effort, we have good documentation on the extent of the terrestrial invasive plant situation within Seattle's major watersheds and have made significant progress in controlling many species. However, we still have to complete surveys for aquatic species, monitor non-native insects and pathogens, and continue eradication and control efforts for terrestrial invasive plants. We anticipate the current level of effort will need to be continued for approximately four more years, until all high risk areas are surveyed and current infestations are either eradicated (small patches) or brought down to levels where they can be more cost-effectively controlled (large patches).

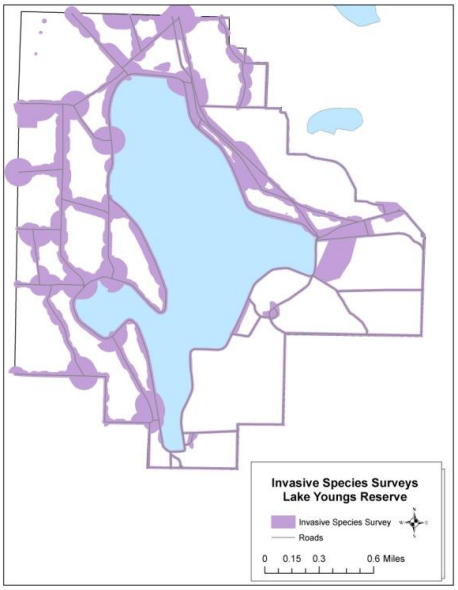
As some or all of the management recommendations for preventing new infestations are implemented, risk of future invasion will be reduced. Increasing development around watershed boundaries and the uncertainty of the effects of climate change, however, means that we will need to continue to do routine annual surveys as part of the Early Detection/Rapid Response protocol.

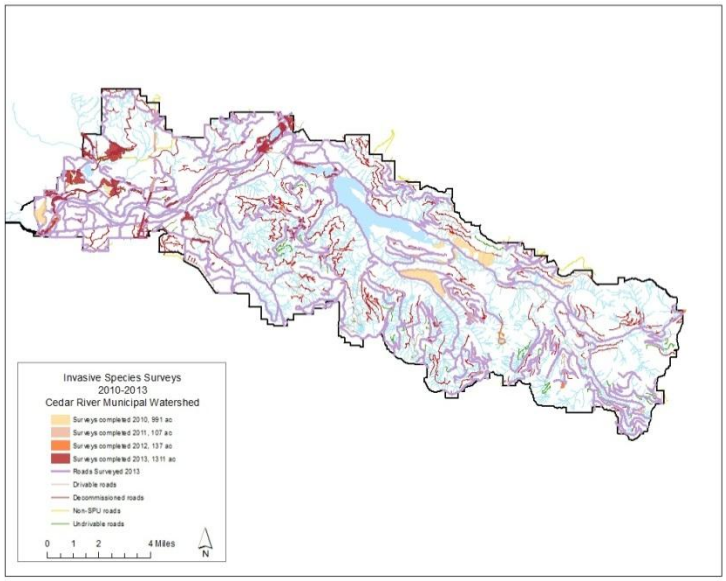
The Invasive Species Program long-term goals are to eradicate all small patches of invasive species that pose a high ecological risk, reduce current size of large infestations to small, manageable levels, restore key sensitive habitats such as wetlands and meadows to fully functioning native plant communities, prevent new infestations to the extent possible, and continue to implement Early Detection/Rapid Response protocols. Although this needs to be an on-going program to continue to deal with current and emerging threats, we anticipate that future Program costs will decrease as surveys are completed and current infestations are reduced. Uncertainties concerning survey results and future invasions, however, make it impossible to accurately estimate costs that far into the future.

Appendix 1. Invasive Plant Species Survey and Treatment through 2013

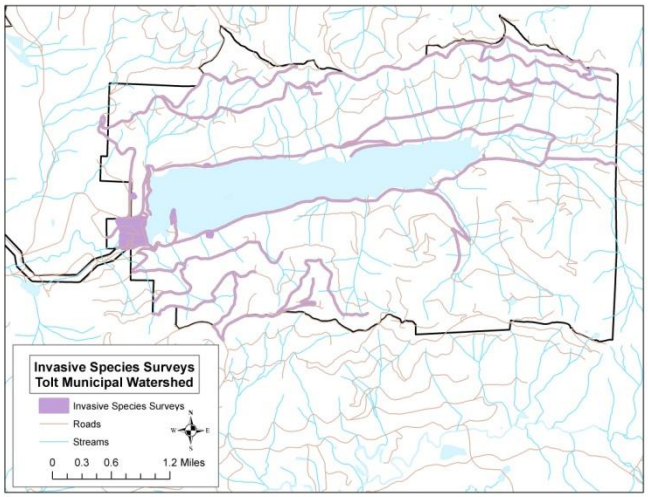
Invasive Plant Species Surveys

Extensive surveys for all invasive terrestrial plant species legally required for eradication or control, plus numerous species that pose significant ecological risk but are not currently required to control have occurred in all three watersheds (shown in purple and brown in maps). In 2007 and 2008 expert botanists surveyed selected areas of the three municipal watersheds for 44 legally required invasive terrestrial plant species (Class A – eradication required, Class B and some C – control of reproduction and spread required), plus 11 recommended control species





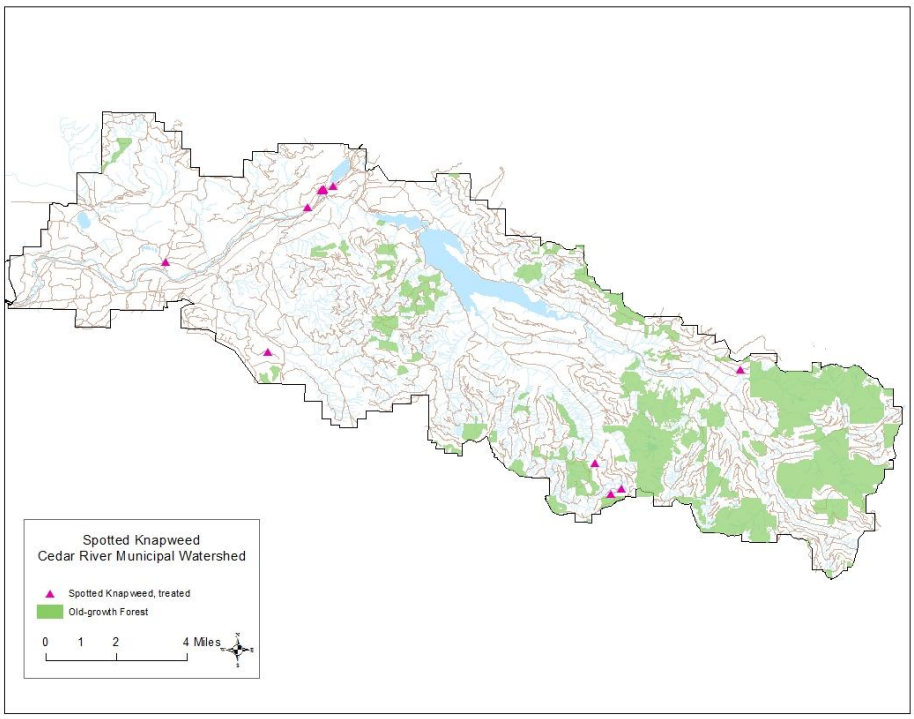
From 2007 through 2013, SPU fish and wildlife staff conducted surveys for numerous invasive terrestrial plant species, both those legally required for control and those that pose significant risks but are not currently legally required for control, as part of the Early Detection/Rapid Response (EDRR) protocol. In 2011 a rotating panel of surveys was developed for wetlands, meadows, riparian areas, decommissioned roads, and gravel pits. The survey schedule is based on degree of risk and frequency of disturbance. Survey intervals vary from one to five years. Implementation of the EDRR rotating panel schedule was delayed because of insufficient staff in 2012, but was started in 2013. In addition, in 2013 extensive off-road surveys were conducted focusing primarily on areas of high risk for knotweed.



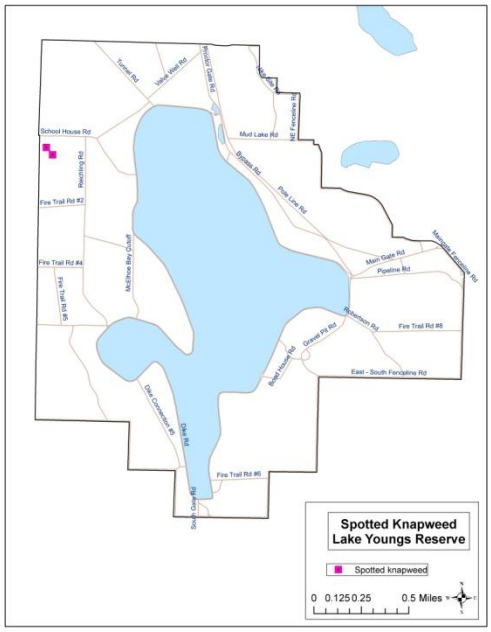
HIGH MANAGEMENT PRIORITY, LEGALLY REQUIRED (species listed alphabetically)

Spotted Knapweed (*Centaurea biebersteinii*)

Spotted knapweed is a very aggressive invasive species, outcompeting most native species in open sunny areas. Initial infestation is usually in disturbed areas, but then it may invade adjacent undisturbed natural areas such as meadows. Up to 146,000 seeds per square meter have been reported in dense infestations, with seeds generally falling adjacent to the parent plant. Seeds can remain viable for over 8 years. It forms dense patches, and also causes decreased water storage capacity and increased soil erosion. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

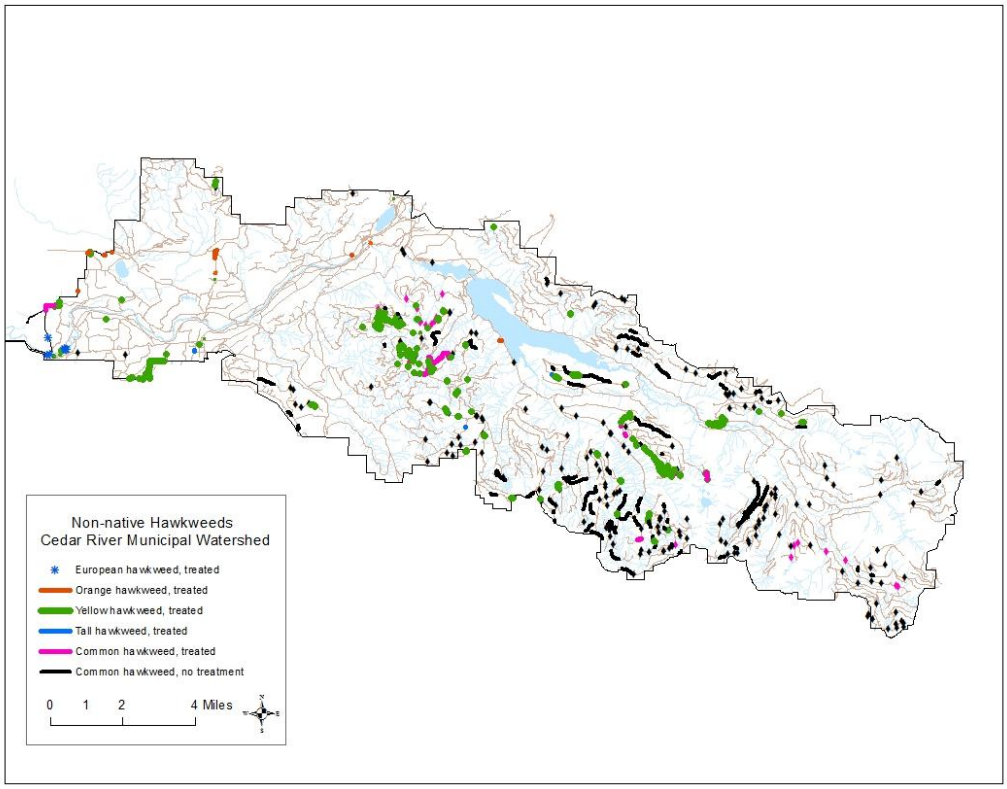


- By 2013, extensive surveys were completed in all three watersheds. Thirteen locations in the Cedar and one at Lake Youngs were found.
- In the Cedar, control on the first patches started in 2005. By 2013, six of the patches were covered with a total of 318 ft^2 of geotextile fabric, one patch has been annually dug since 2005 (4,442 ft^2), and the remaining six patches were small populations or single plants that were dug once and have not re-grown.
- All patches in the Cedar will be monitored and controlled annually until they are eradicated.
- A single patch on a heavily used hard-packed gravel site near the fenceline was found at Lake Youngs. It consisted of about 2,700 plants scattered over 8,900 ft^2. Because of the difficulty of treating this site, it was decided to use a targeted hand-spray of the herbicide aminopyralid, a chemical with an extremely low toxicity to animals and birds. Treatment started in 2011. In 2012 only 27 rosettes and no bolting plants were found and treated. In 2013 16 plants were found and treated. Treatment will continue annually until the patch is eradicated.



Non-native Hawkweeds (*Hieracium sp.*)

Invasive hawkweeds are found in sunny areas, mainly along roads and in disturbed areas. They spread very rapidly by seeds and quickly out-compete native plants, forming dense homogeneous mats that can have as many as 3,200 plants per square yard. Seeds remain viable for 2 to 3 years. They pose an ecological threat of invading and degrading meadows and other open habitats, and are a top priority of the Washington Invasive Species Council. Initial general surveys have been completed, plus we conduct ongoing annual surveys of high risk areas for new infestations. Surveys generally occur during flowering, with timing variable depending on elevation. Five invasive species were mapped in the Cedar (see map), two in the Tolt, and one at Lake Youngs. Control has been ongoing since 2007 for all known European, orange, yellow, and tall hawkweed patches (see following information by species).

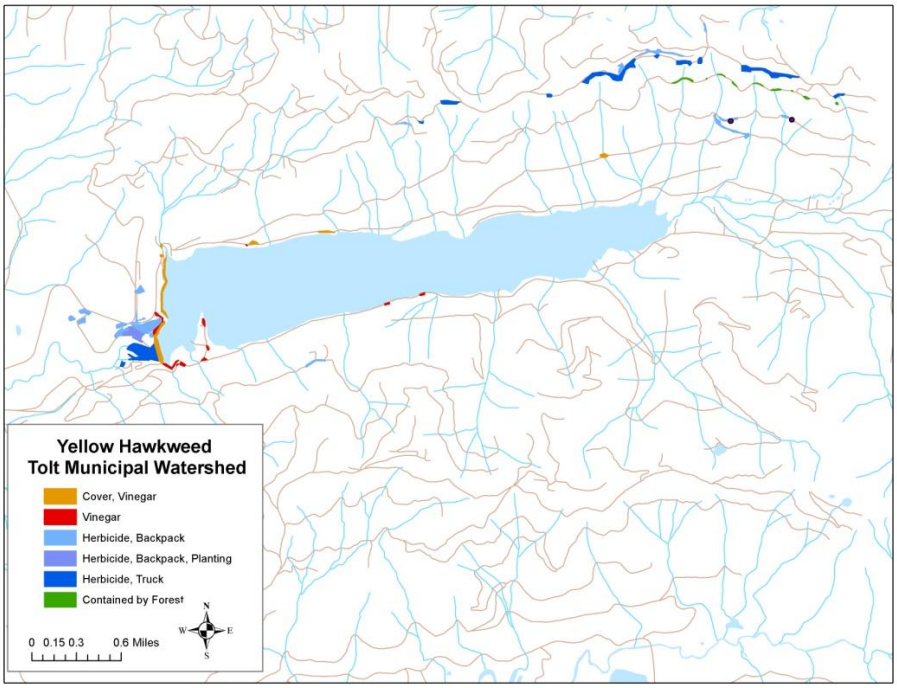


1. European hawkweed (*Hieracium sabautum*) - Eradication is legally required.
    - A total of seven patches have been found in the Cedar, none in the Tolt or Lake Youngs. The largest patch was found in September 2009. A total of 520 plants were dug in 2009 and 2010 scattered over a 3,400 ft^2 area. Over 500 ft^2 was covered with fabric in 2011 and 2012. Two additional small patches were found in 2011, one in 2012, and one in 2013. All have been covered with geotextile fabric in an attempt to starve the roots.

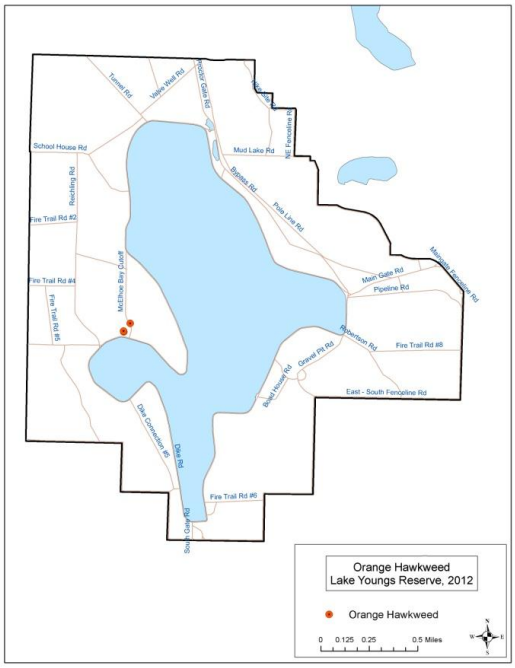
2. Yellow (meadow) hawkweed (*Hieracium caespitosum)* – Control is legally required.
    - Extensive locations throughout Cedar and Tolt, mainly in upper elevations. None found at Lake Youngs.
    - Control in of yellow hawkweed in the Cedar started in 2005. By 2013 a total of 14.66 acres was being treated.

- From 2005 through 2013, a total of 3.16 acres of fabric was installed and maintained multiple times per year on dense patches.
- From 2010 through 2013, a total of 7.4 acres with scattered, isolated individuals was experimentally treated with ordinary 5% table vinegar several times a year. This treatment appears efficacious and cost-effective if conducted during warm dry weather.
- Several decommissioned roads have been planted with conifers to provide sufficient shade over time to suppress or eliminate the hawkweed. In 2007, 4.2 acres of decommissioned roads was planted with 3,100 conifer trees and 1,000 shrubs. In 2011, a total of 1.5 acres of decommissioned roadbed was planted with trees spaced about six feet apart. Much of the infested area on these decommissioned roads was also seeded to a grass mixture that should help provide competition while the trees and shrubs are growing.

- Control in the Tolt was initiated in 1999 and was incorporated into the Invasive Species Program in 2010. In 2013 over 76 acres of infested area was treated in the Tolt Municipal Watershed, Regulating Basin, and pipeline right-of-way.
  - Infestations spread over approximately 65.5 acres were treated with the herbicide aminopyralid (outside hydrographic boundary or greater than 250 feet from the reservoir).
  - 6.4 acres had fabric installed and maintained multiple times per year on dense patches, plus 5% table vinegar treatment of isolated plants near the fabric.
  - 4.4 acres of scattered isolated individuals were treated with 5% vinegar several times a year.
  - In addition, there was about 2.8 acres of infested area on decommissioned roads that is being contained by native forest.



3. Orange hawkweed *(Hieracium aurantiacum*) – Control legally required.
    - Two adjacent locations at Lake Youngs, 18 locations in Cedar mainly in lower elevations, none in the Tolt.
    - Control in Cedar started in 2005. By 2013 over one acre was being controlled and eight of the patches appeared eradicated.
        - Over 10,000 ft^2 of fabric was installed and maintained multiple times per year on dense patches.
        - About 10,000 ft^2 of isolated individuals were treated with ordinary 5% vinegar several times a year.
        - A total of 27,500 ft^2 is controlled by routine mowing of lawns at the Cedar Falls and Landsburg complexes to prevent seeding.
    - Control of the patch spread over approximately 5,000 ft^2 at Lake Youngs started in 2011 and included a combination of covering dense patches (768 ft^2) and vinegar on isolated individuals. By 2013, the fabric was removed and only a few scattered individuals remained.



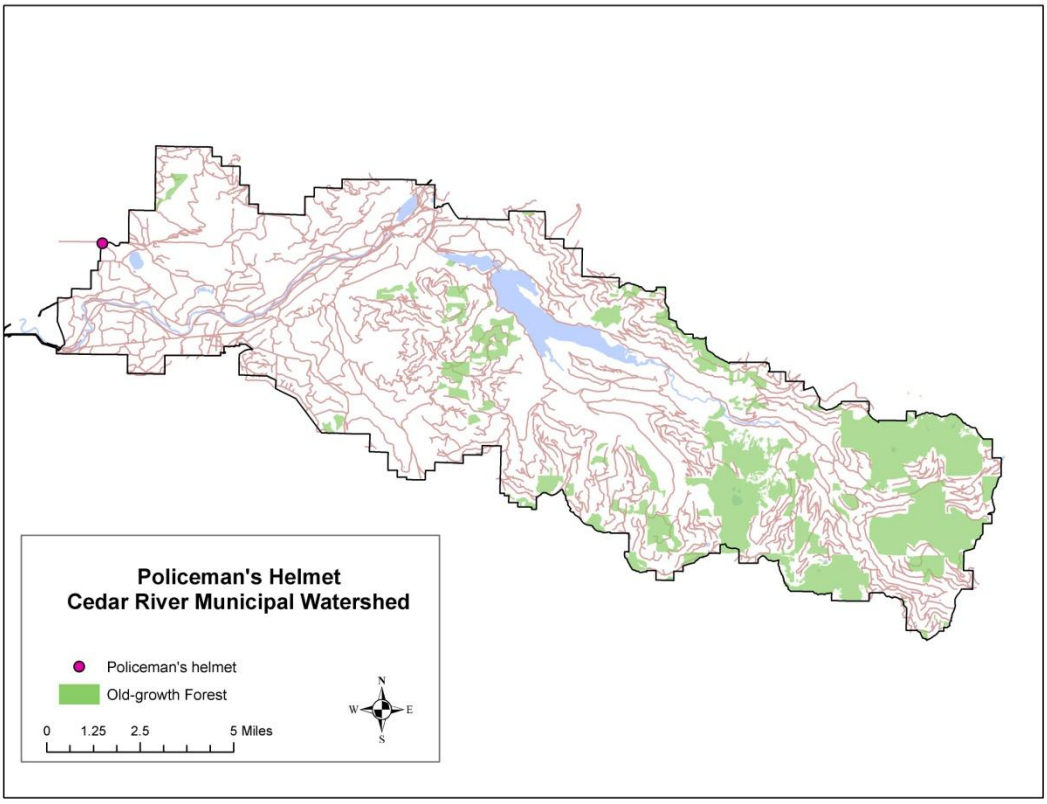
4. Tall hawkweed (*Hieracium piloselloides)* - Control legally required.
    - Three locations in the Cedar, two isolated and the other adjacent to yellow hawkweed, none in the Tolt or Lake Youngs
    - Control of two Cedar patches began in 2009, with the third found in 2013.
        - 200 ft^2 of fabric was installed & maintained on the first isolated patch
        - The patch near the yellow hawkweed was covered and maintained as part of that larger patch
        - The new patch found in 2013 consisted of small scattered individuals and so were treated with table vinegar.

5. Common hawkweed (*Hieracium lachenalii*) – Control legally required where feasible and a local threat is posed
    - Extremely abundant throughout higher elevations in Cedar; occasionally seen in Tolt, with no reported occurrences at Lake Youngs.
        - By 2013, over 18,000 ft^2 fabric was installed and maintained multiple times per year on several dense high-risk patches in the Cedar
        - By 2013, in the Cedar over 5.5 acres of scattered isolated individuals posing high ecological risk was monitored and experimentally controlled by ordinary 5% vinegar or digging
    - In 2009 ten monitoring sites were established in the Cedar to evaluate the risk of common hawkweed spreading into nearby meadows or old-growth forest. It was spreading so quickly in two of the sites that in 2012 they were switched to control sites.
    - In the Tolt common hawkweed is treated if it occurs in conjunction with yellow hawkweed or if small isolated patches are seen.

Policeman's helmet (*Impatiens glandulifera*)

Policeman's helmet is highly invasive in riparian areas and other moist natural areas. It can grow to ten feet tall and is partially shade tolerant. Consequently it poses a large threat to the understory in our native moist forest. Each plant can produce up to 800 seeds and eject the seeds over 20 feet, with seeds remaining viable for over 18 months. Control is legally required.

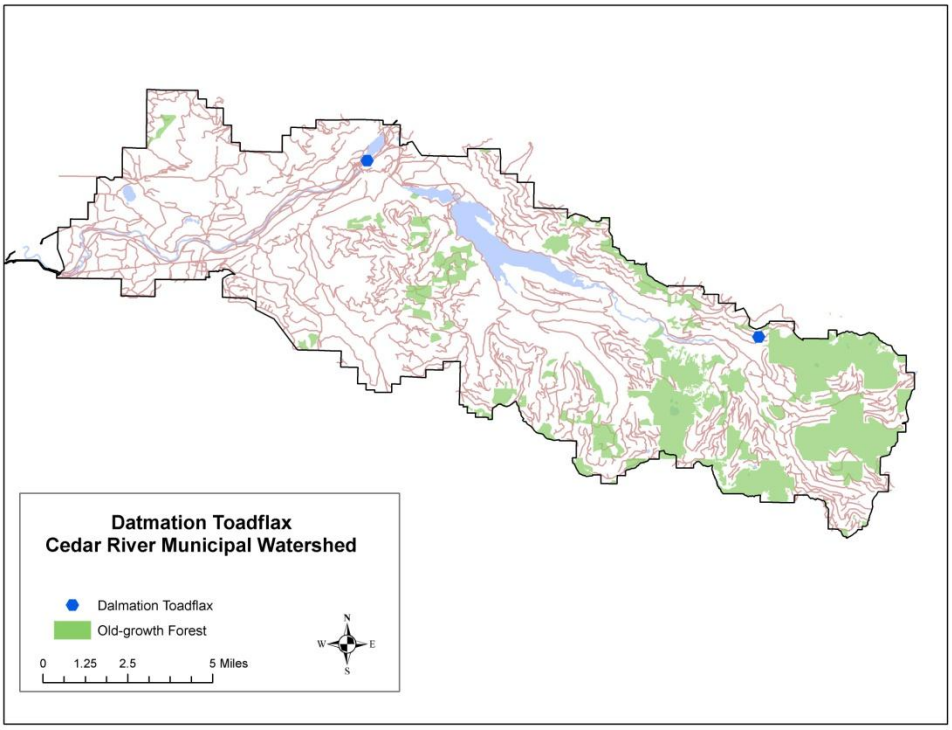
- By 2013, extensive surveys were completed in all three watersheds and only one location in the Cedar was found, with none in the Tolt or Lake Youngs.
- Five plants were dug out in 2009 and 1 plant was dug in 2010. No plants were found in 2011, 2012, or 2013.
- The area will continue to be monitored annually and all plants found will be dug prior to seeding.



Dalmatian Toadflax (*Linaria dalmatica*)

Dalmatian toadflax is a strong competitor with native plants in dry, open natural areas. It spreads by deep creeping root systems, forming dense mats, as well as producing up to 500,000 seeds per plant. Seeds may live up to ten years in the soil. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

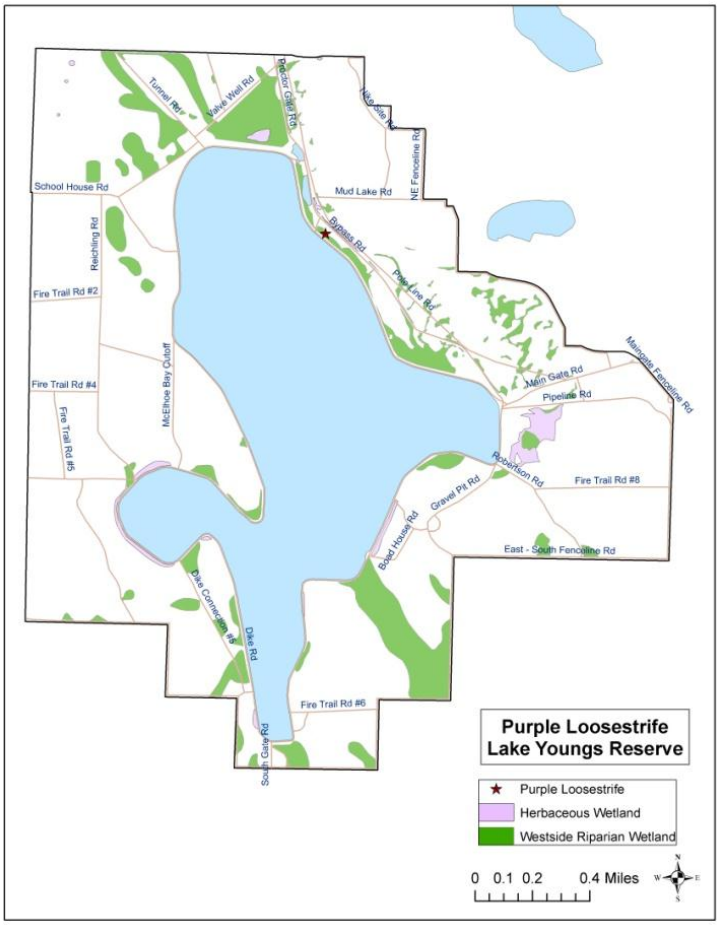
- By 2013, extensive surveys were completed in all three watersheds and only two locations in the Cedar were found. One site was in the Cedar Falls Compound and the other near the end of a road decommissioned in 1994 and likely introduced via contaminated straw.
- The two patches were covered with a total of 326 ft^2 of geotextile fabric in 2008. The fabric was maintained annually in 2009 and 2010, with little to no growth near the edges.
- The patch at Cedar Falls was uncovered in 2010 and no further growth was seen. The patch on the decommissioned road has not been checked since 2010 due to staff shortages, but remains covered.



Purple Loosestrife (*Lythrum salicaria*)

Purple loosestrife poses a major threat to wetland and riparian areas and can even invade drier sites. Each plant can produce 2.7 million seeds which spread easily by wind or water and over 400,000 seed per square meter of wetland have been documented. The seed life is currently unknown, but is expected to be a minimum of five years. In addition, it has a taproot and fibrous rhizomes that form dense mats. Dense stands of purple loosestrife can easily choke out native plants, taking over entire wetlands and disrupting normal ecosystem function. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

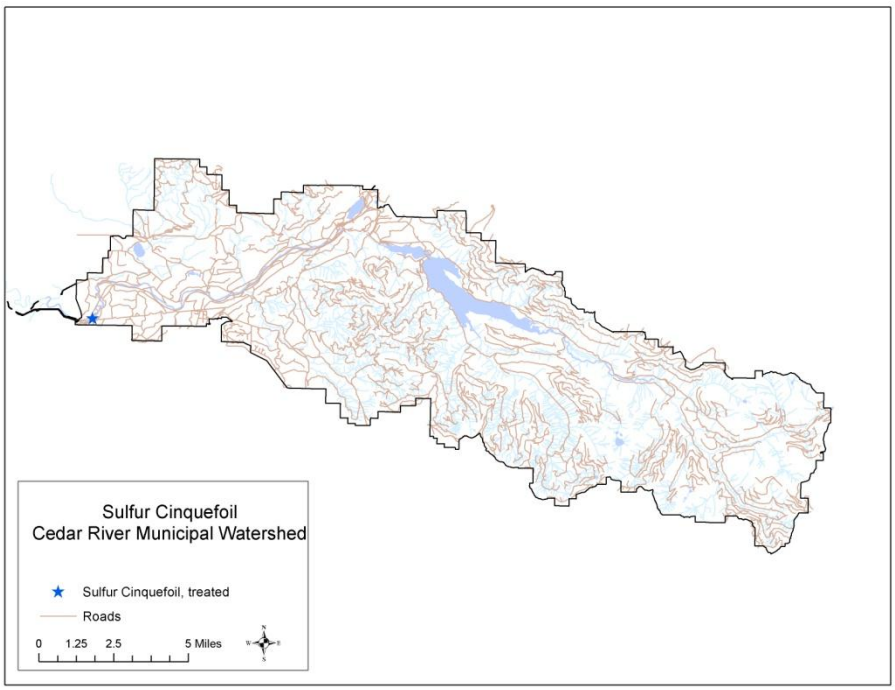
- By 2013, extensive surveys were completed in all three watersheds. Only a single infestation was found, in a small wetland at Lake Youngs, spread over an area of about 4,000 ft^2.
- Control started in 2010. All plants were dug and removed from the site prior to their dispersing seed, including 417 large plants plus many more small seedlings. Over 22 large garbage bags of plant material were removed from the site in 2010, about 3 bags in 2011, 5.5 bags in 2012, and 3 bags in 2013.
- All plants will continue to be dug and removed prior to setting seed annually until the patch is eradicated.



Sulfur Cinquefoil *(Potentilla recta)*

Sulfur cinquefoil is highly invasive perennial plant, forming dense mats of vegetation. It has a deep taproot surrounded by shallow spreading side roots. Seed remain viable in the soil for at least four years, and the plant can also sprout from root fragments.

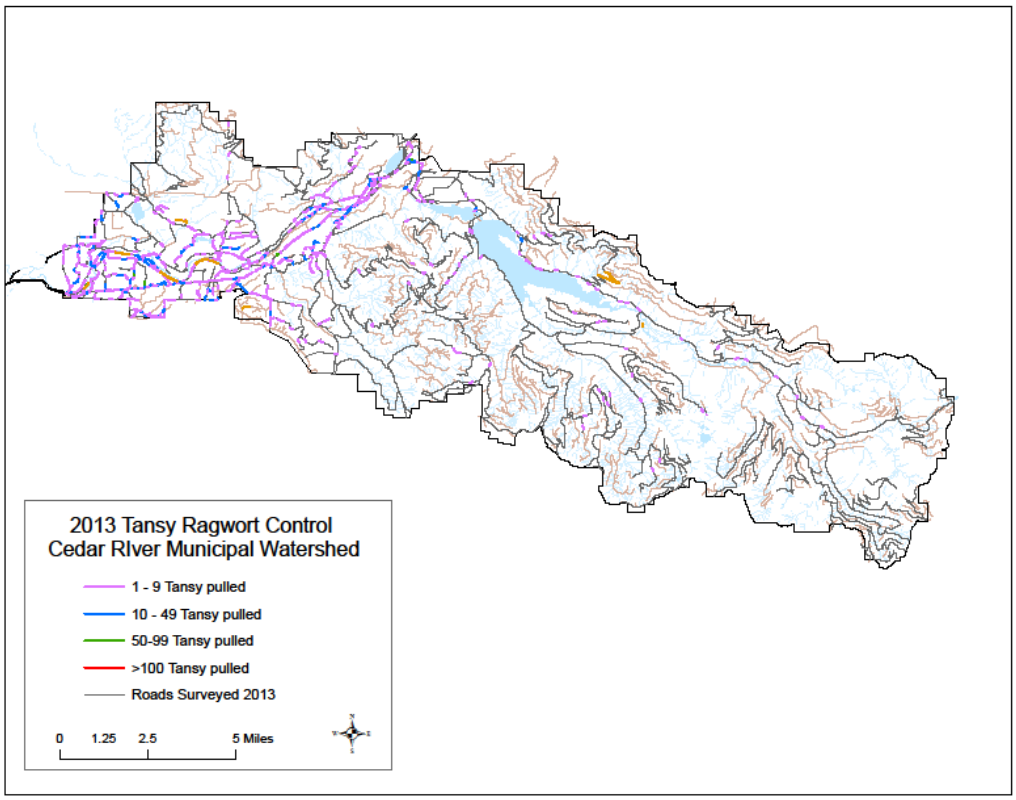
- In 2012 a patch of sulfur cinquefoil covering about 400 ft^2 was found in the Cedar, adjacent to the Landsburg Dam. As many roots as possible were hand-excavated, then the area was covered with geotextile fabric. It will be monitored and maintained until the patch is eradicated.
- In 2013 another patch was found just across the Cedar River from the first. It was covered with about 100 ft^2 of fabric and will also be monitored and maintained until eradicated.



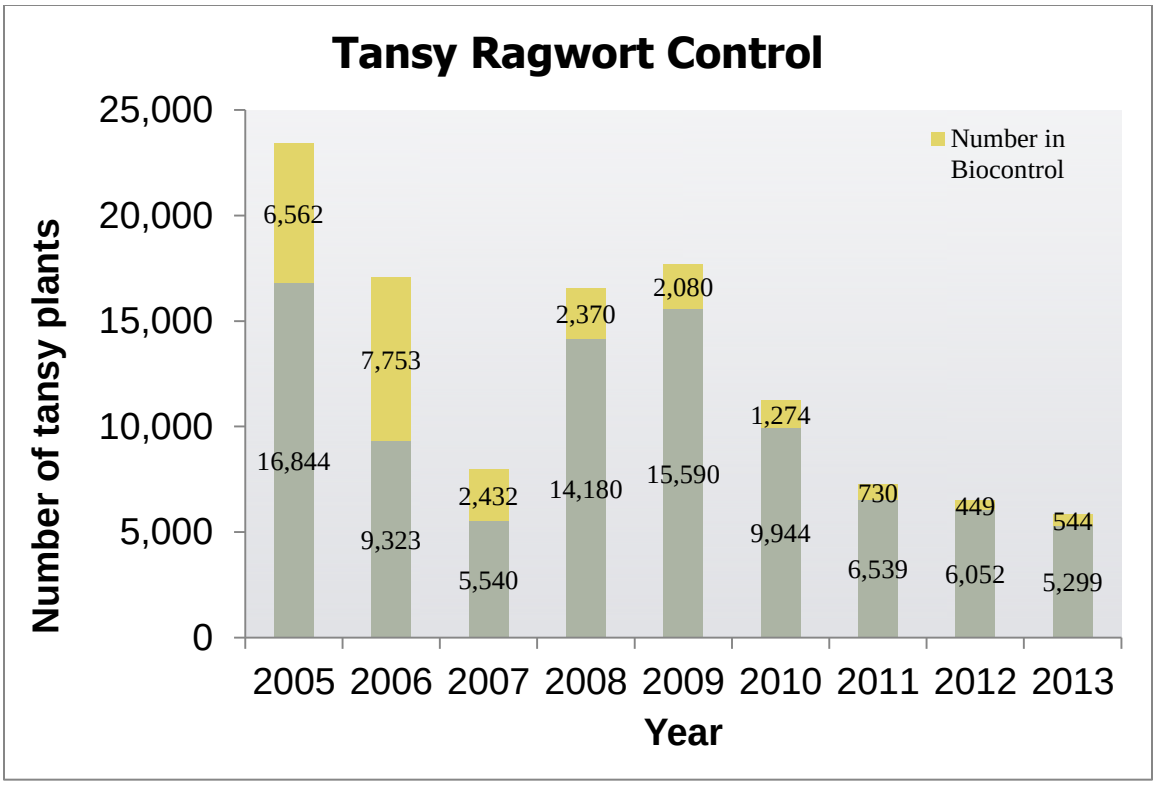
Tansy Ragwort (*Senecio jacobaea)*

Tansy ragwort is commonly found in sunny, frequently disturbed areas. It is most often a biennial, producing a basal rosette in the first year and a flowering stalk (generally 2 to 4 feet tall) in the second year. Many plants (20 to 40% of a population) have been documented to be perennial. Each plant can produce up to 150,000 seeds which can remain viable for up to 15 years. It spreads rapidly by seed and root fragments, and can easily become large monocultures, outcompeting native plants. It is toxic to ungulates if eaten in sufficient quantities. Control is legally required, and it is a top priority of the Washington Invasive Species Council.

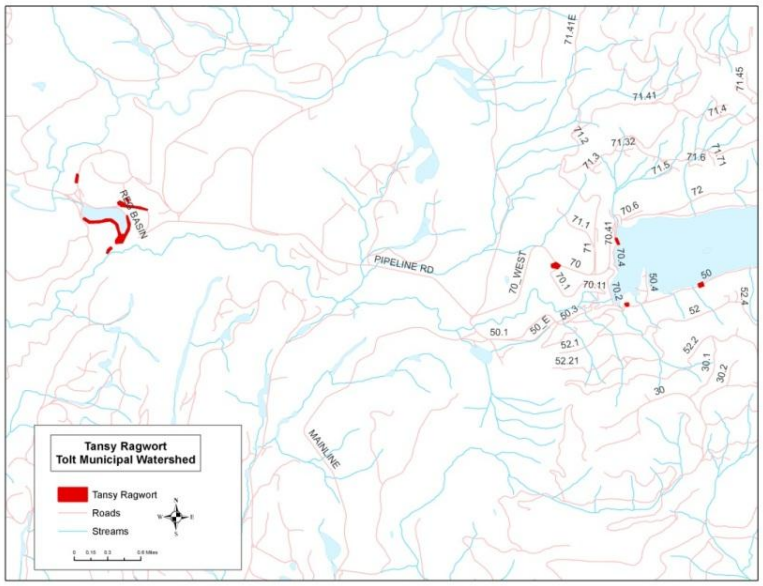
- We have attempted to control all plants annually in the Cedar since 2002 by pulling the entire plant during flowering prior to seed set. Flowers are clipped, bagged and disposed of; remaining plant parts are left to desiccate on site.
- The largest infestations in the Cedar are along well-traveled roads in the lower watershed.



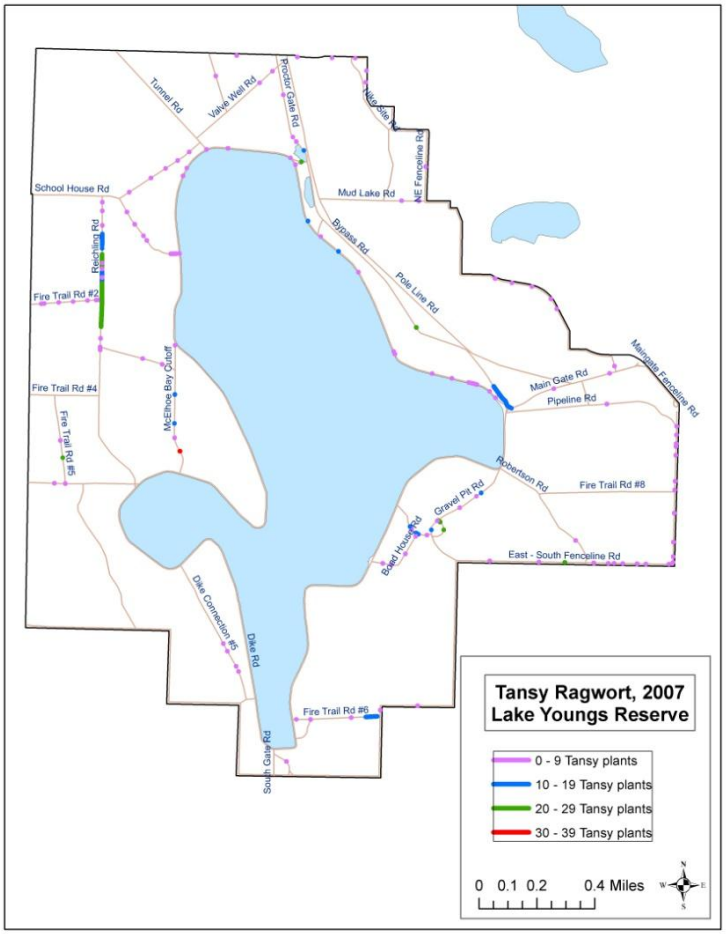
- Biocontrol experiments with tansy flea beetle were established at eight sites in the Cedar, four where bolting plants were counted and clipped and four isolated locations where plants were counted but allowed to flower and seed (to encourage more rapid population growth of the beetles). As seen in the following graph, total number of plants in biocontrol areas has dropped dramatically (from 6,562 in 2005 to 544 in 2013).
- Total number of plants has been dropping consistently since 2009, indicating the long-term control effort is becoming successful in reducing the overall population and soil seed bank. Variability in number of bolting plants from 2005 to 2009 is likely due to amount of soil disturbance. Seeds are stimulated to sprout by ground disturbance, so we are working with SPU Operations crews to try to minimize the amount of ground disturbance during routine road maintenance projects.



- Tansy ragwort seeds remain viable for up to 15 years, so in the Cedar we expect to see dramatic decreases in number of plants by 2017 if the current level of control is maintained.
- There is a dense infestation adjacent to the Tolt regulating basin. Most plants there (>9,000 plants) are pulled annually by SPU Transmission staff or contractors. Starting in 2011 the Invasive Species Program assisted by controlling a large infestation of tansy ragwort in the main gravel pit and on SPU land in the upper watershed. Scattered plants in higher elevations were also treated in starting 2011.



- In 2007 a complete survey was conducted at Lake Youngs. Prior to 2011 plants there were sporadically controlled along main roads by Lake Youngs staff. In 2011 and 2012 the Invasive Species Program assisted in control of tansy at Lake Youngs in off-road areas (gravel pit, fields, mitigation restoration site). In 2013 Lake Youngs staff implemented a more comprehensive control effort along all roads.

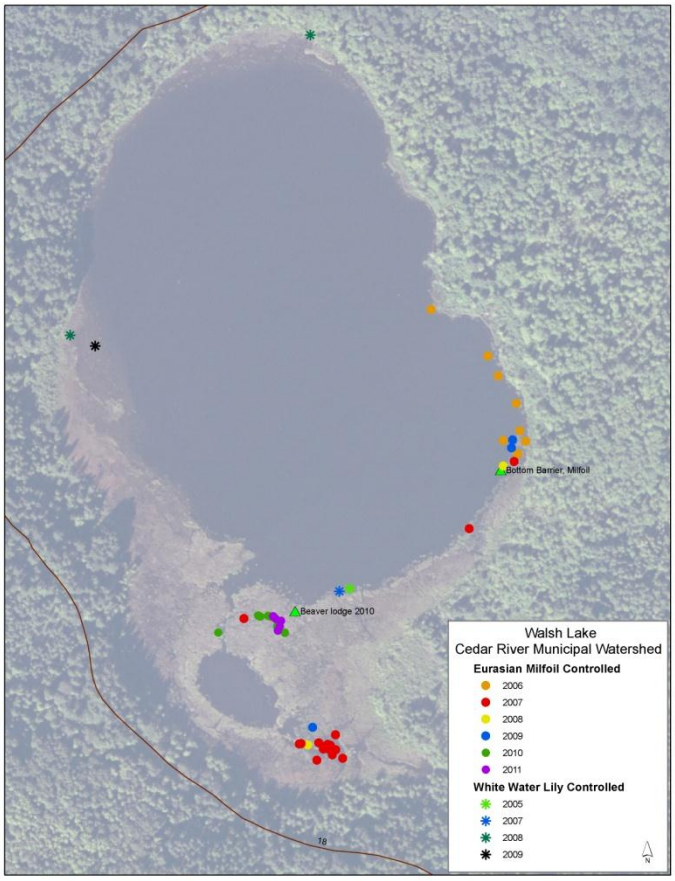


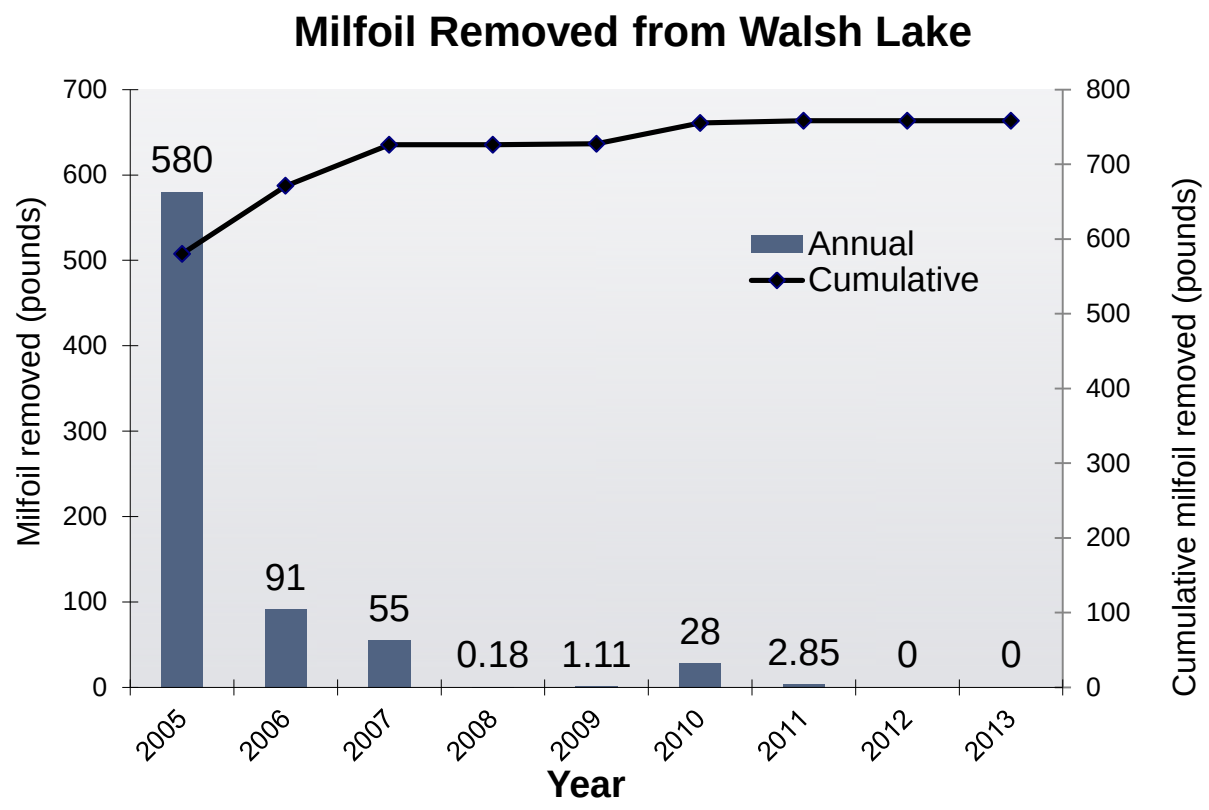
HIGH MANAGEMENT PRIORITY – VERY HIGH ECOLOGICAL THREAT (species listed alphabetically)

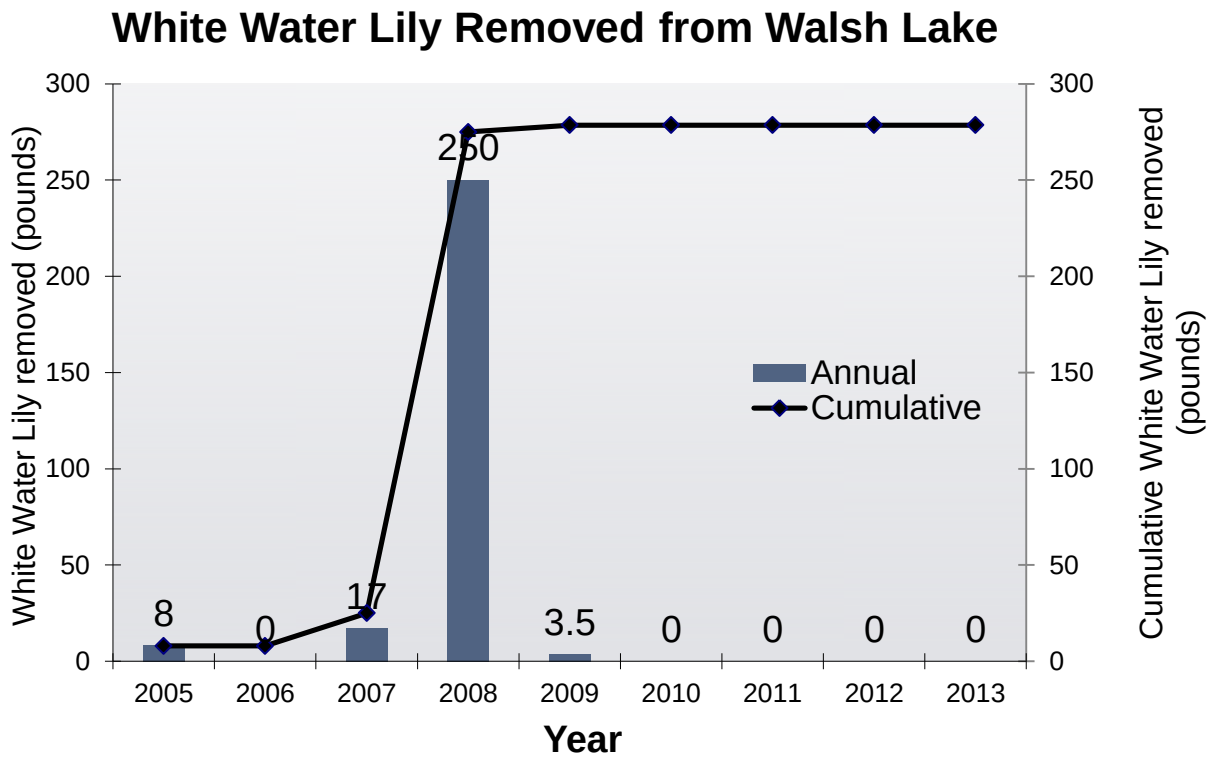
Eurasian Water-milfoil (*Myriophyllum spicatum*) and **White Water Lily** (*Nymphaea odorata)*

Eurasian milfoil is an extremely invasive aquatic plant that can completely clog native water bodies, forming huge stagnant masses that rob oxygen from the water and increase sedimentation rates. It reproduces very rapidly, primarily through plant fragments. Control is not legally required because it is widespread, but is highly recommended. It is a top priority of the Washington Invasive Species Council. White water lily can also form huge mats, shading out native aquatic plants. Because there are few white water lily plants in the Cedar, they are controlled along with the milfoil.

- Milfoil was first detected in Lake Youngs in 1992. An intensive, expensive eradication effort occurred from 1993-1996. No milfoil has been detected in surveys there from 1997 to the present.
- Milfoil was first detected in Walsh Lake, a small natural lake in the western portion of the Cedar, in 2001.
- Because the risk of re-infesting Lake Youngs was high, control (diver hand pulling) of both milfoil and white water lily began in 2005. At that time a containment curtain was installed around the initial milfoil infestation.
- Diver surveys and hand pulling has continued annually, multiple times per year from 2005 through 2012.
- In 2008 the containment curtain was removed and in 2009 a bottom barrier over the initial infestation was installed.
- Total pounds of milfoil removed have greatly decreased over the years, but eradication is complicated by extensive beaver activity (see following graph).
- No milfoil was found in 2012 or 2013. In order to be declared eradicated, five consecutive years with no detections must be completed.
- Total pounds of white water lily removed from Walsh Lake have generally been small, with the exception of 2008, when an unusually large amount was removed (see following graph). This illustrates the ability of white water lily populations to very quickly expand.



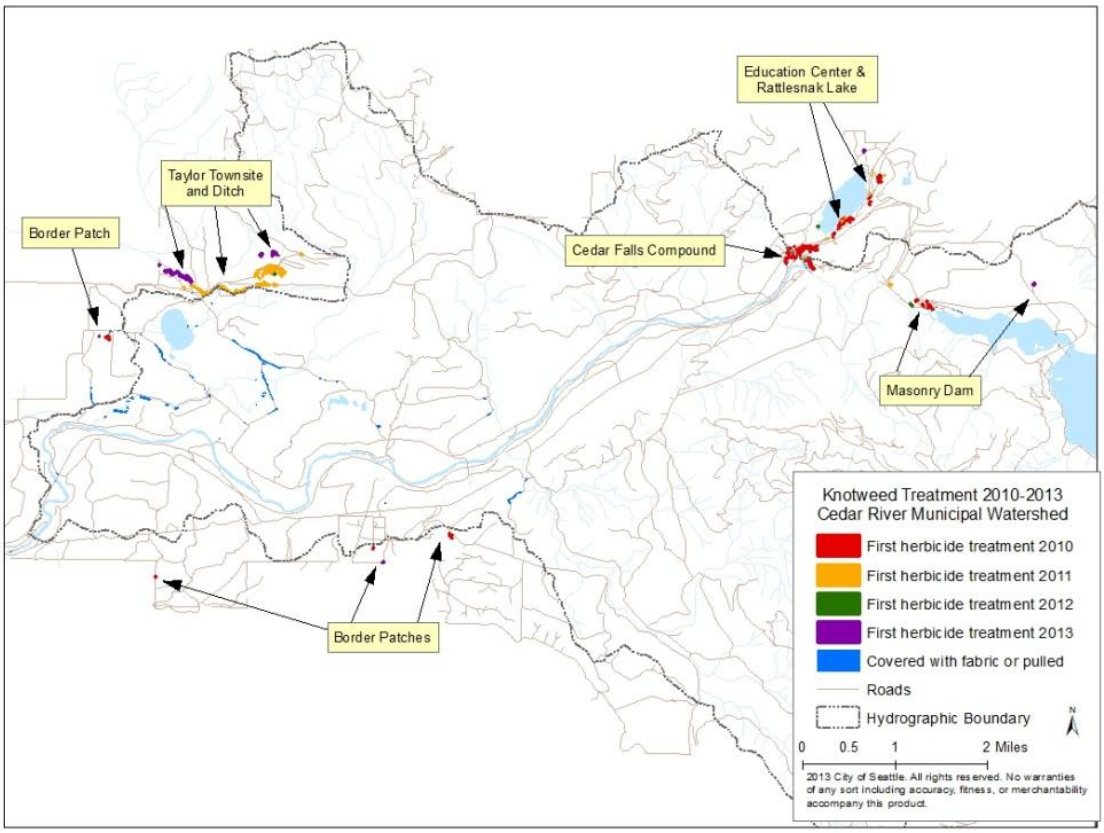

Milfoil Removed from Walsh Lake
Milfoil removed (pounds)
Cumulative milfoil removed (pounds)
Annual
Cumulative
580
91
55
0.18
1.11
28
2.85
0
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year


White Water Lily Removed from Walsh Lake
White Water Lily removed (pounds)
Cumulative White Water Lily removed (pounds)
Annual
Cumulative
8
0
17
250
3.5
0
0
0
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year

Bohemian Knotweed *(Polygonum x bohemicum)*

Because it is so widespread, knotweed control is not yet legally required throughout King County. In 2013 control along the Cedar River was legally required. Knotweed poses one of the greatest ecological threats of any non-native invasive species in the watersheds, and is a top priority of the Washington Invasive Species Council. Knotweed forms huge dense monocultures, threatening riparian and wetland habitat, and potentially aquatic habitat. It spreads easily by water, primarily by dispersal of tiny root or stem fragments that form new colonies. The species present in the Cedar is Bohemian knotweed (*Polygonum x bohemicum*), a hybrid between Japanese and giant knotweed. This hybrid is more difficult to control than either of the parent species and may produce a higher percentage of viable seeds, although no evidence of reproduction through seeding has been found in the Cedar.

- By 2013 extensive surveys throughout the three watersheds were complete, with large numbers of patches mapped in the Cedar and a single small patch in a gravel pit in Lake Youngs. None has been found in the Tolt.
- In 2013 all known knotweed patches in the Cedar were mapped and total area estimated to be about 22.5 acres.



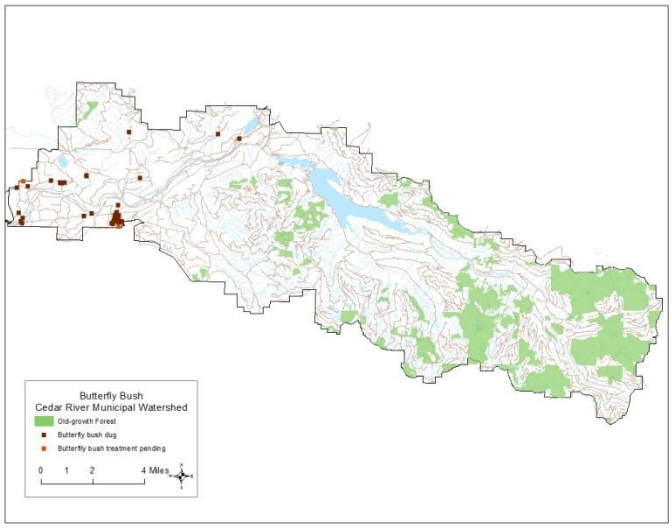
- From 2004 through 2013 a total of 4.5 acres of the smaller patches was treated by covering with fabric. The fabric is maintained every two to six weeks during the growing season (less frequent maintenance is required the longer it is covered) for at least six years in order to starve the roots. When fabric was removed after six years, very small patches appeared dead. However, larger patches quickly re-grew, indicating this treatment may be insufficient to kill large root masses.

- In 2010, Seattle City Council passed an ordinance allowing the limited use of the herbicide imazapyr (an herbicide with extremely low toxicity to animals and birds) to treat knotweed in the municipal watershed. The ordinance authorized only three seasons of herbicide treatment (2010 – 2012), after which the ordinance sunset. It was found that three or fewer herbicide treatments are insufficient to kill large patches of knotweed. So in 2013, a follow-up ordinance was passed allowing three more years of treatment.
- 2010 – 2013, a total of 7.7 acres of knotweed was treated with a total of four annual treatments of imazapyr.
- 2011 – 2013, a total of 7.9 acres was treated with three annual treatments of imazapyr.
- 2012-2013, a total of 0.3 acres was treated with two treatment of imazapyr.
- In 2013, a total of 2.15 acres of newly discovered knotweed was treated for the first time
- In 2012 the single patch at the Lake Youngs gravel pit was treated with glyphosate. No new growth was seen in 2013.

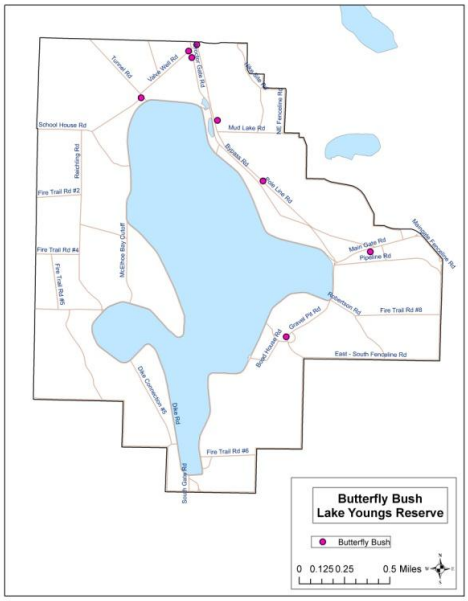
HIGH MANAGEMENT PRIORITY - HIGH ECOLOGICAL THREAT, LIMITED DISTRIBUTION (species listed alphabetically)

Butterfly Bush (*Buddleia davidii*)

Butterfly Bush is increasingly being recognized as major invasive species in Washington, particularly in riparian areas. It has a wide tolerance for environmental conditions and can produce up to 3 million seeds per plant, with seeds remaining viable for up to five years. In recent years it has been documented reproducing in a wide variety of natural habitats, including gravel bars in rivers, riparian forests, and upland habitats. It can re-sprout from rootstock and cut stems may grow into new plants. Control is not legally required because it is widespread, but is highly recommended. It is a top priority of the Washington Invasive Species Council.



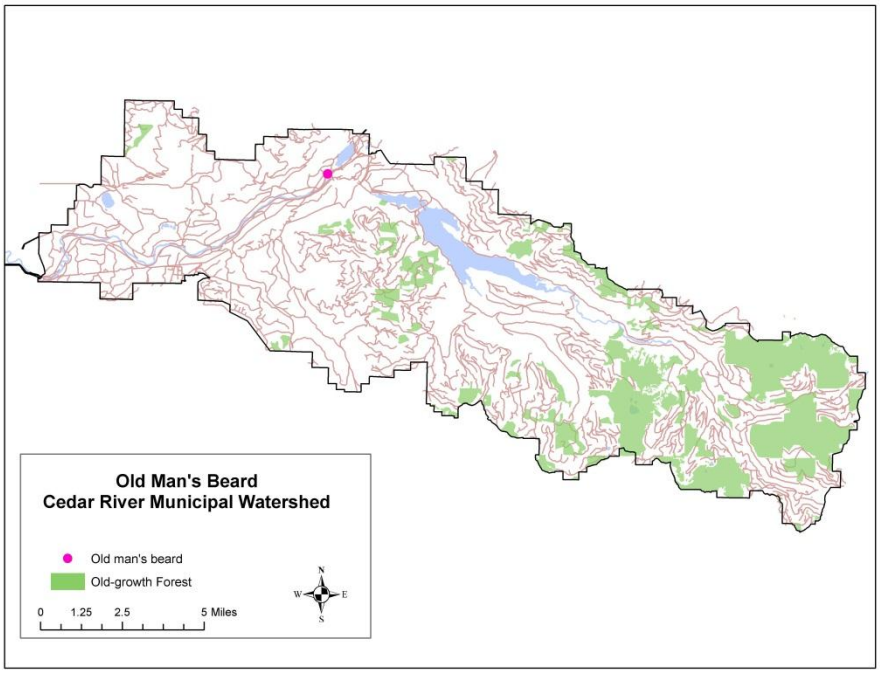
- By 2013, extensive surveys were completed in all three watersheds. 34 locations in the Cedar, eight at Lake Youngs, and a large infestation in a gravel pit near the Tolt regulating basin were found.
- All sites in the Cedar had relatively few plants. Control (grubbing out the entire plant, including roots) of all but one site in the Cedar started in 2008 and has continued annually (total of 160 plants pulled through 2013, with some sites treated more than once).
- By 2013 only two live plants were seen and pulled, with no live plants found at any of the other previously treated sites.
- In 2009 over 400 plants were pulled out of the very large infestation in the Tolt gravel pit. Many more plants were grubbed out in 2011 and 2012. By 2013, all large plants had been removed.
- The Lake Youngs patches consisted of about 40 plants. Control started in 2012. In 2013 only three live plants were found and treated.



Old Man's Beard (*Clematis vitalba*)

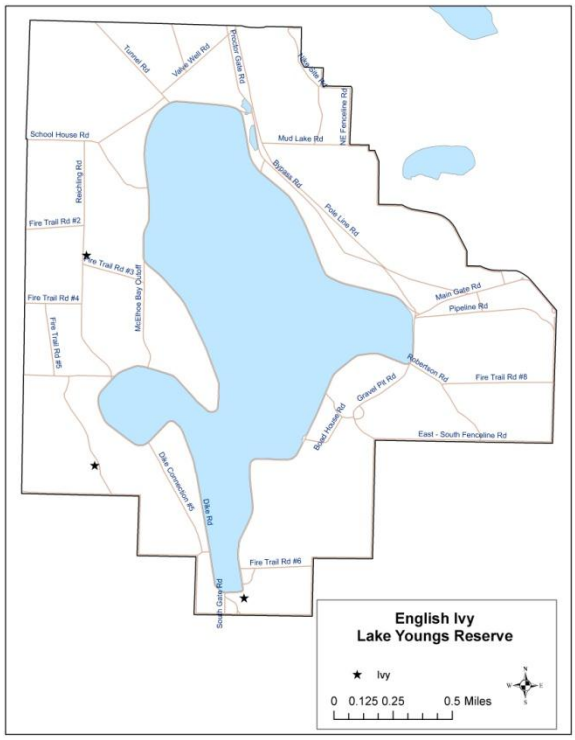
Old man's beard is a woody vine that can reach 100 feet long. It will both cover the ground and completely blanket trees and shrubs, eventually killing them. Each plant can produce more than 100,000 seeds annually, plus vine fragments can root and form new plants. Control is not legally required because it is widespread, but is highly recommended.

- By 2013, extensive surveys were completed in all three watersheds. Only one plant near the Cedar Falls compound in the Cedar was found.
- Because of the very limited amount present and the high risk posed by this species, in 2011 this plant was completely grubbed out all.
- No growth was seen in 2012 or 2013. The area will be monitored annually, and if any plants appear they will be treated as needed.

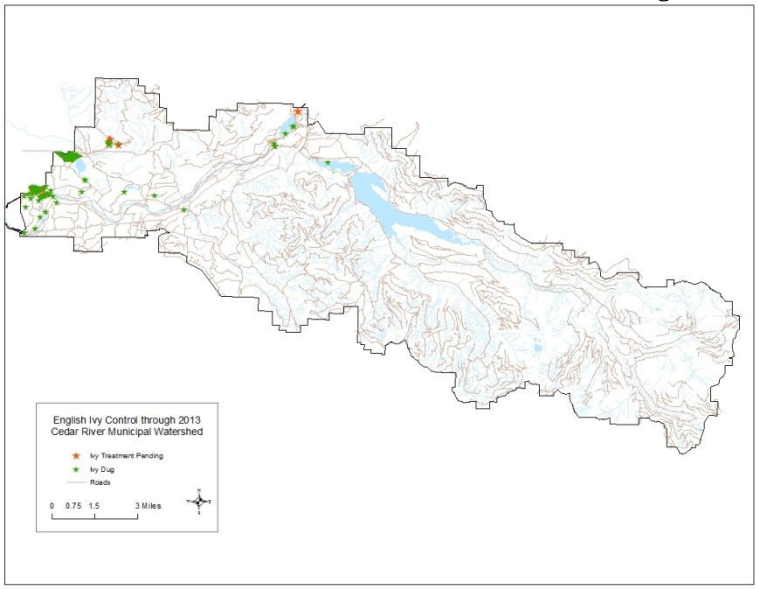


English Ivy (*Hedera helix*)

English Ivy is an extremely aggressive invasive species that is shade tolerant and thus poses a great risk to native forest ecosystems. It easily out-competes native forest understory, and when it climbs on trees will eventually girdle and kill the tree. Control is not legally required because it is widespread, but is highly recommended. Control requires grubbing out all portions of the plant, including all trailing roots. Eradication of an ivy patch usually requires several years of grubbing because it is very difficult to extract all the root material.



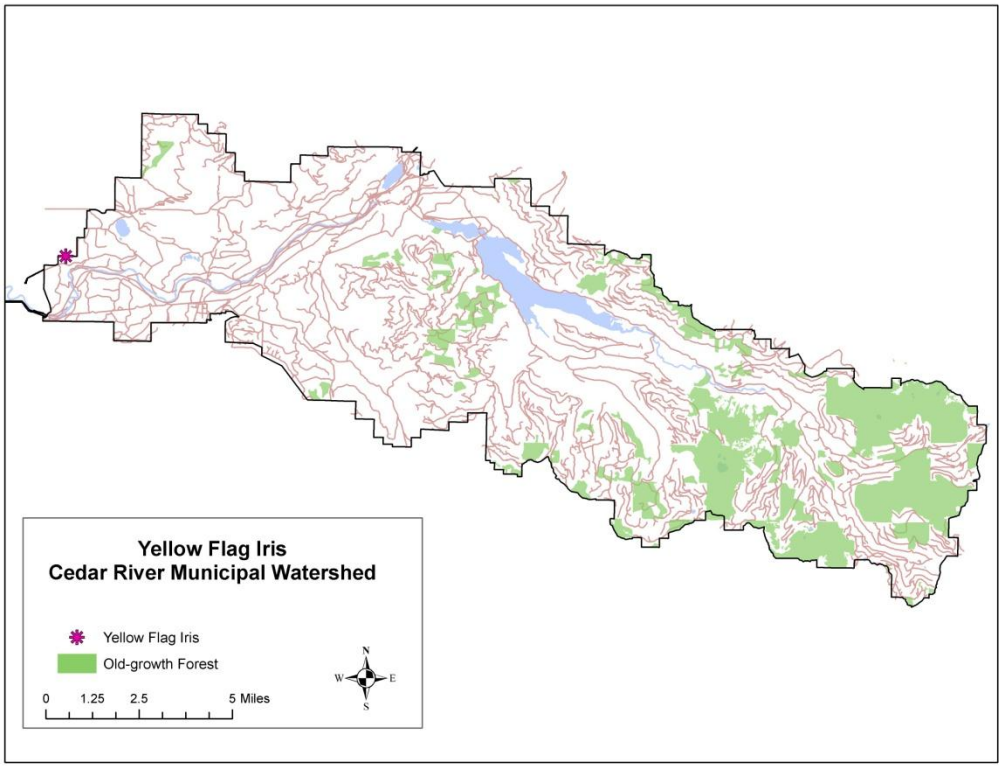
- By 2013, extensive surveys were completed in all three watersheds. 57 sites in the Cedar encompassing 108.5 acres, and three small patches at Lake Youngs were documented.
- One site at Lake Youngs was grubbed out in 2007. It has been monitored annually and no re-growth has occurred. The remaining two sites were grubbed out in 2011 and no growth was seen at either site in 2012 or 2013.
- Of the 108.5 acres in the Cedar, two forest patches with ivy sporadically scattered throughout them covered 107 acres. The remaining 55 patches were small and isolated, totaling only about 1.5 acres.
- Treatment of the first sites in the Cedar started in 2008. By 2013, 49 of the sites had received at least an initial treatment and nine sites showed no re-growth since 2011.
- All treated sites are monitored and re-treated as needed and as funding allows.
- The remaining untreated sites in the Cedar will be treated when funding and staffing allow.



Yellow Flag Iris (*Iris pseudacorus*)

Yellow flag iris is an aggressive invader in riparian areas and shallow open water. It spreads quickly by rhizomes, plant fragments, and seeds and forms dense stands of hundreds of connected plants. It traps large amounts of sediment, raising elevation and creating new streambanks. It can reduce stream width by up to ten inches per year. Once established, it is very difficult to control. Control is not legally required because it is widespread, but control is highly recommended.

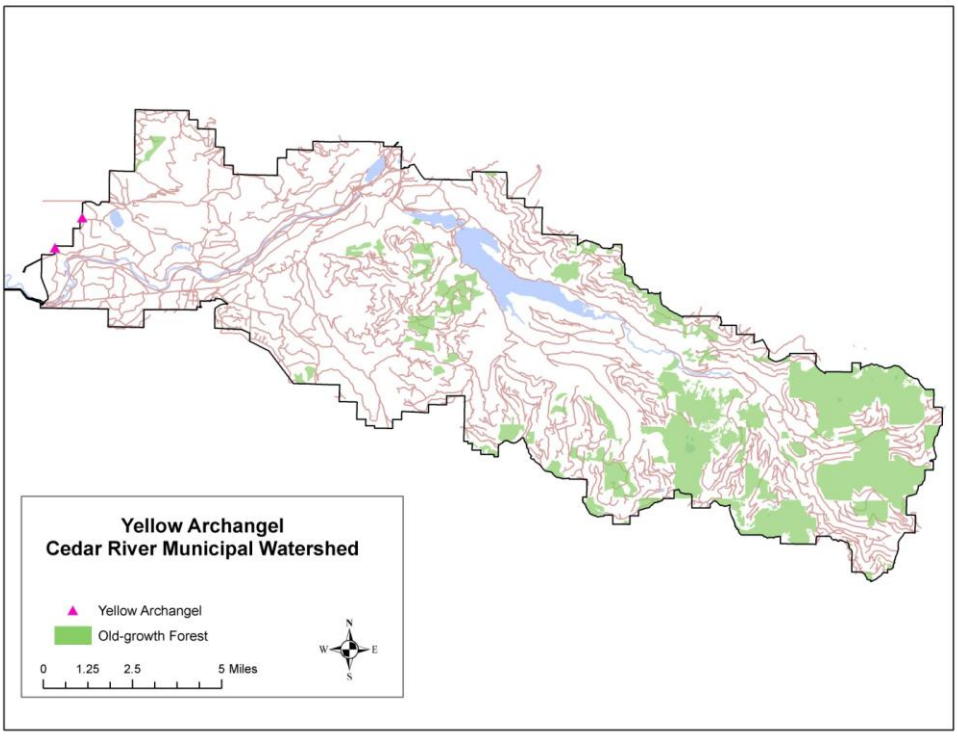
- By 2013, extensive surveys were completed in all three watersheds. Only a single plant on the western fenceline in the Cedar was found in 2007 and was dug.
- This area was re-surveyed in 2011, and the plant was not found.
- The area is monitored periodically and if any plants are found, they will be treated immediately.



Yellow Archangel (*Lamiastrum galeobdolon*)

Yellow archangel is a creeping groundcover that can grow in full sun or full shade. It forms large dense mats, crowding out native plants. Because it is shade tolerant, it poses a significant threat to native forest understory. Control is not legally required because it is widespread, but is highly recommended.

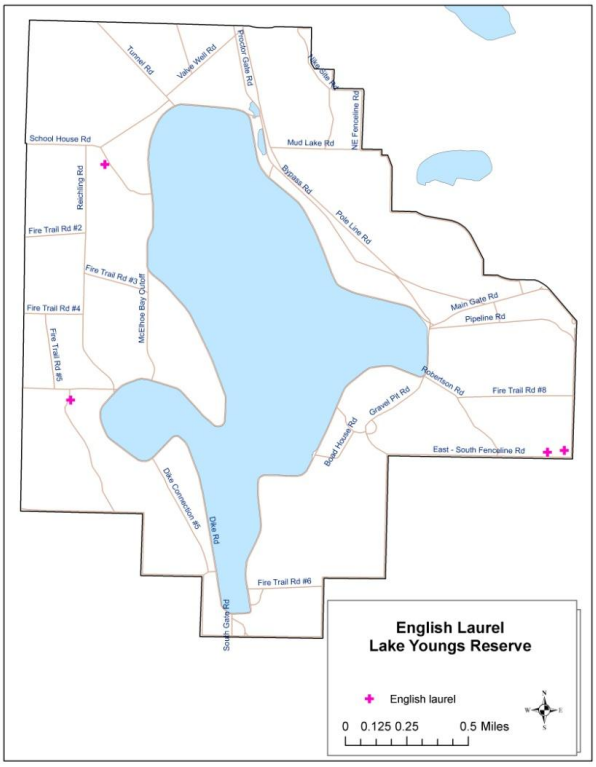
- By 2013, extensive surveys were completed in all three watersheds. Only two small infestations along the western border of the Cedar were found. Because of the very limited amount present and the high risk posed by this species, both patches were treated.
- The first patch was found within the forest near the western border. It was covered in 2009 with a total of 630 ft^2 of geotextile fabric. Little to no growth was seen in 2010 – 2013. This small forest patch will be monitored and treated annually until it is eradicated.
- The second patch was discovered in 2010 and was covered with a total of 3,350 ft^2 of geotextile fabric in 2010 and 2011. This is a massive patch along the fenceline, and the understory of the forest on the neighboring property is completely blanketed with the plant. The goal for this site is to stop the plant from reaching the forest on the opposite side of the road because it will be impossible to control along the fenceline as long as the infestation is present on the neighboring property. The fabric along the fence will be maintained as funding and staffing allow. The nearby forest will be monitored annually and any small infestations will be treated immediately.
- In 2013 a patch was found in the gravel pit at Lake Youngs and was treated. It will be monitored and re-treated until eradicated.



English Laurel (*Prunus laurocerasus*)

English laurel is a large evergreen shrub/small tree that can form dense thickets. It grows well in both sun and shade, and thus is a threat to native forest understory. It is now found in natural areas and is the second most common invasive tree species in Washington. It is fast-growing and can out-compete most native understory trees and shrubs. Control is not legally required because it is widespread, but control is highly recommended in natural areas.

- By 2013, extensive surveys were completed in all three watersheds. Four trees were found in the understory of a conifer forest at Lake Youngs, with none in the Cedar or Tolt.
- In 2008 the largest tree was treated with 50% glyphosate and water using the frill method (cut a small cup in the bark and place a small amount of the mixture in the cup) as a part of a forest restoration project treating a large holly infestation. In 2012 this tree was starting to regrow.
- In 2012 three laurel plants were treated with 100% glyphosate using the cut stump method, where a very small amount of glyphosate was painted onto the stump (no chemical reached the forest floor). All plants were dead in 2013.

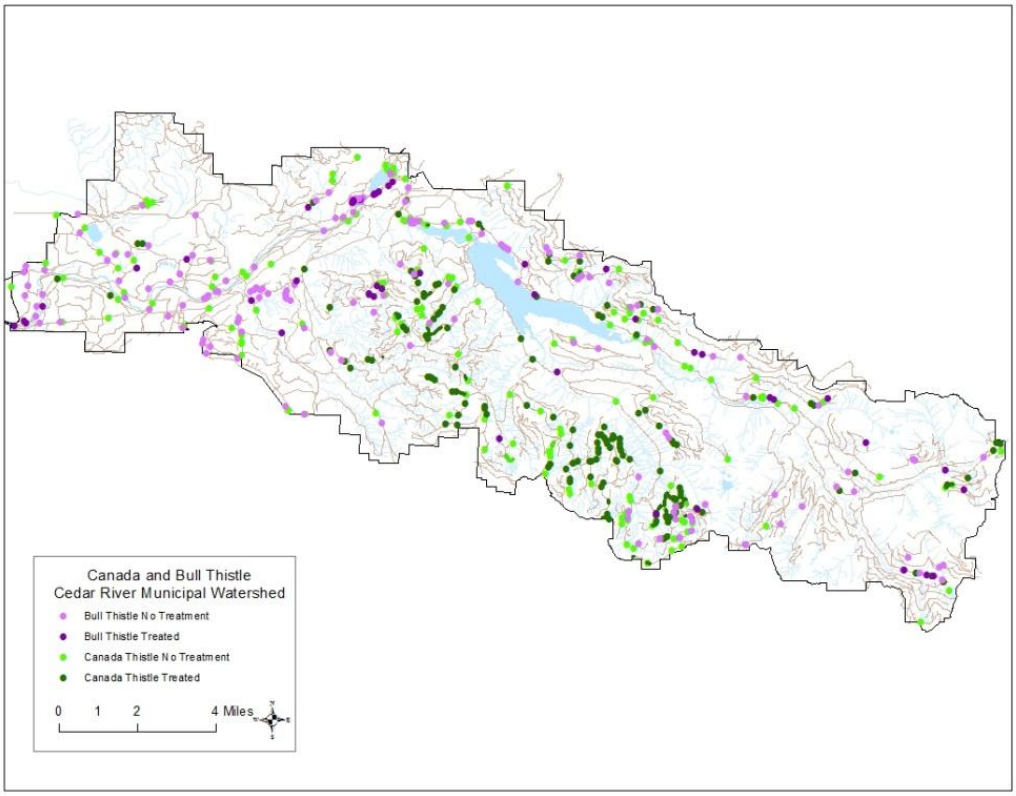


MEDIUM MANAGEMENT PRIORITY – HIGH ECOLOGICAL THREAT, WIDESPREAD
(species listed alphabetically)

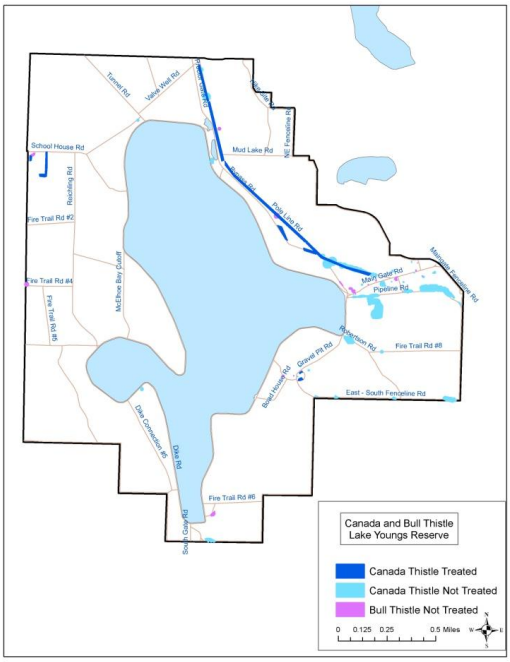
Non-native, Invasive Thistles (*Cirsium arvens, Cirsium vulgare)*

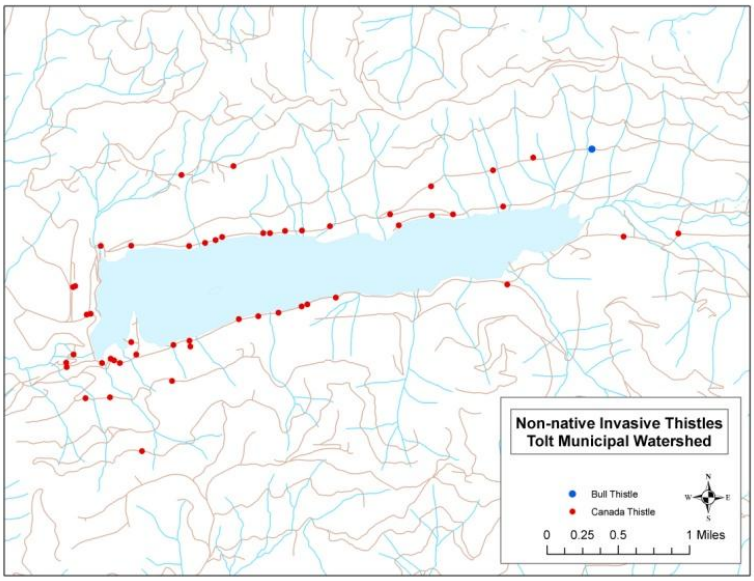
Both Canada thistle and bull thistle are common invasive species in open sunny areas. They thrive in areas of disturbance and are a particular threat to meadows that have frequent natural disturbance such as high mountain beaver populations or elk use. Bull thistle is a biennial that spreads only by seed, while Canada thistle is a perennial that spreads both by seed and lateral root growth, with small detached root fragments able to grow into new plants. Roots may extend both horizontally and vertically up to 15 feet. Consequently, Canada thistle forms dense thickets and poses a greater risk to native ecosystem functioning than bull thistle. Canada thistle seed can survive over 20 years if buried in at least eight inches of soil, but less than five years in shallow or frequently disturbed sites.

- Initial surveys for both Canada and bull thistle were completed in 2007 and 2008 as part of the overall invasive species surveys conducted by expert botanists. Additional surveys are conducted annually by SPU biologists during other surveys. Both species are very widespread throughout the Cedar, with Canada thistle predominating in both the Tolt and at Lake Youngs.
- In 2010 a biocontrol experiment using Canada thistle gall flies was initiated in two locations in the Cedar: one along a ROW and one in a higher elevation meadow. Both sites will be monitored and used as gall fly source populations if they are successful.
- From 2007 through 2013 over 1,000 bull thistle and 3,200 Canada thistle have been pulled, cut, or sprayed with 5% vinegar in the Cedar in an attempt to weaken the roots and decrease the infestation. Control has focused on high value wildlife habitats, small isolated populations, and roads either already decommissioned or scheduled for decommissioning.



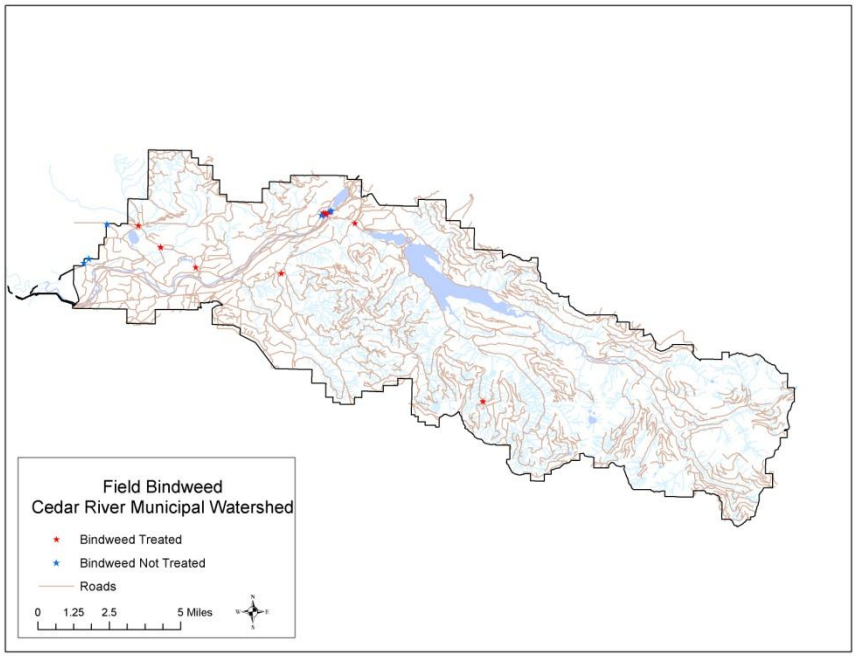
- In Lake Youngs there were large patches of Canada thistle in the gravel pit, open fields, and along main travel corridors. In 2012 control began in the gravel pit, fields, and along the Pole Line Road in an attempt to limit the dispersal to other areas of the reserve. Control continued in 2013, with all treated patches significantly reduced.
- In the Tolt there was a small dense infestation of Canada thistle in the gravel pit near the Regulating Basin. In 2012 it was treated along with numerous other invasive species in the pit, in an attempt to limit dispersal in the gravel as it is used on roads projects throughout the watershed. Plants around the lake are pulled as staffing and funding allow.





Field Bindweed (*Convolvulus arvensis*)

Field bindweed is a deep rooted perennial vine that both grows along the ground and climbs aggressively. It flourishes in a wide variety of conditions, from full sun to full shade. It reproduces from roots, rhizomes, stem fragments, and seeds that remain viable for over 20 years. Roots spread widely both vertically and horizontally, forming dense mats. Once established, it is nearly impossible to eradicate. It is very widespread, so is not legally required to control, although control, especially of new infestations, is highly recommended.

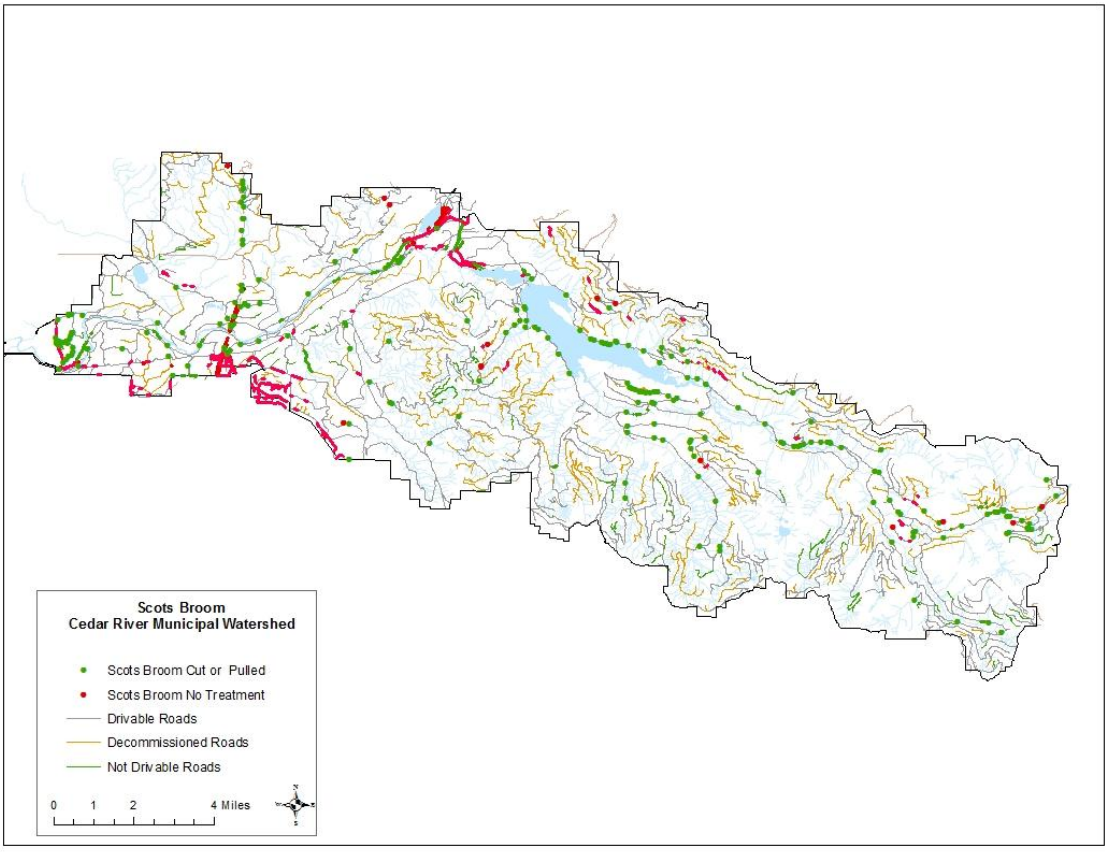


- Surveys were completed in 2007 and 2008 as part of the overall invasive species surveys conducted by expert botanists. Some large and a few limited infestations were found in the Cedar, one infestation in the Tolt, and one at Lake Youngs.
- From 2007 – 2013 ten small patches in the Cedar have been dug or covered with geotextile fabric.
- In 2012-13 the large patch in the Tolt regulating basin gravel pit was treated, along with numerous other invasive species in the pit, in an attempt to limit dispersal in the gravel as it is used on roads projects throughout the watershed.
- In 2012-13 the patch in the gravel pit at Lake Youngs was successfully treated.

Scot's Broom (*Cytisus scoparius*)

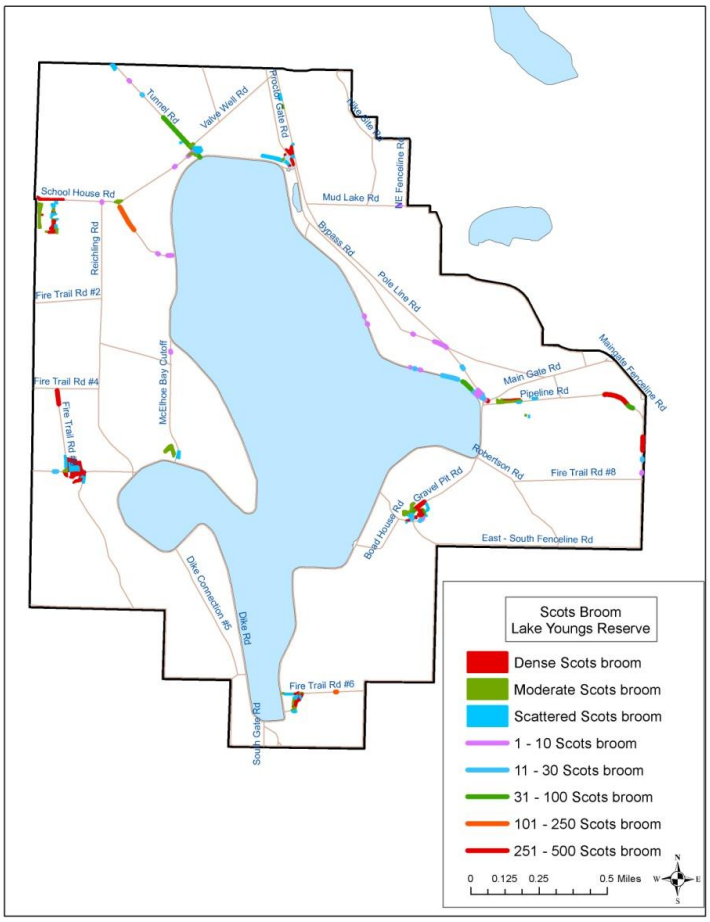
Scot's broom is an extremely common invasive species that can form large, impenetrable thickets in dry sunny areas. Each plant can produce over 10,000 seeds which remain viable for more than 60 years. Dense thickets of Scots broom displace native plants, prevent native tree regeneration, and are a potential fire hazard because of their flammability. In addition, the seeds are toxic if eaten. Scot's broom is legally required for control along I-90 east of North Bend, and recommended for control wherever feasible. It is a top priority of the Washington Invasive Species Council.

- We started surveys along roads in the Cedar in 2004 and update annually as new plants are found during general surveys.
- Limited surveys have been conducted in restoration sites and other open areas.



- The largest infestations are along the southern border, in rights of ways, and in developed areas around Cedar Falls and the Masonry Dam
- Thousands of plants have been cut or pulled in the Cedar from 2005 through 2013. Target areas include:
    - Small isolated plants to ensure new thickets are not established (most of the control seen in the upper elevations are this type, usually from seeds in contaminated gravel)
    - Areas in and near major gravel pits and gravel storage areas, to help reduce spread of the seed through road and culvert projects
    - Areas of infestation adjacent to or near areas of recent disturbance, such as windthrow, to ensure these natural areas are not infested.

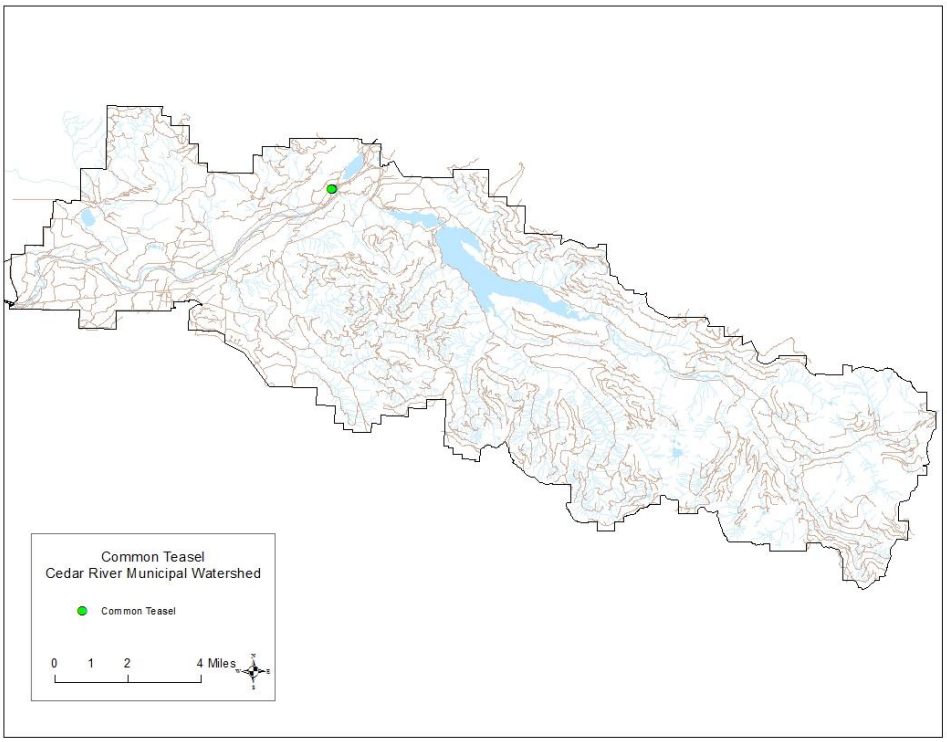
- Infested areas along roads slated for decommissioning are targeted for dense planting with native conifer trees, to help shade out the Scot's broom over time.
- Scot's broom is also removed as part of habitat restoration projects, including controlling invasion after the 45 Road Ecological Thinning Project and the expansion of the BPA ROW in 2003, as well as several experimental planting projects in the BPA ROW.
- In 2007 a survey along all the roads at Lake Youngs was completed and Scot's broom was mapped by density categories (see map).
- Starting in 2011, Scots broom in three fields and the gravel pit at Lake Youngs was controlled by digging. Areas were seeded heavily to grass to provide competition
- Surveys for Scots broom have not yet been completed at the Tolt, although there were dense infestations in the Regulating Basin gravel pit and near the Vista House.
- From 2011 through 2013 all the large Scots broom plants in the gravel pit and near the Vista House and on the slopes west of the Vista House were pulled. Control will continue as staffing and funding allow.



Common Teasel (*Dipsacus fullonum*)

Common teasel thrives in open sunny habitats with moderately moist soil. It can create large dense monocultures, and is highly competitive in open grassy habitats. It has a deep taproot up to two feet long, and a single plant can produce up to 30,000 seeds. The plants generally die after they set seed, and reproduction is entirely by seed.

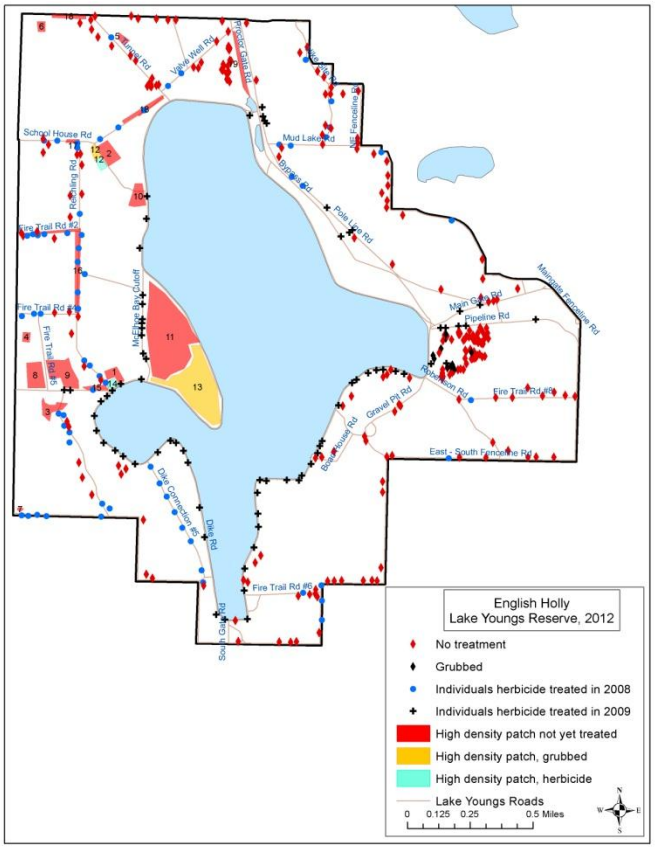
- By 2013, extensive surveys were completed in all three watersheds. Only a single small patch was found in the Cedar. Control (pulling) started in 2011, and continued through 2013.



English Holly (*Ilex aquifolium*)

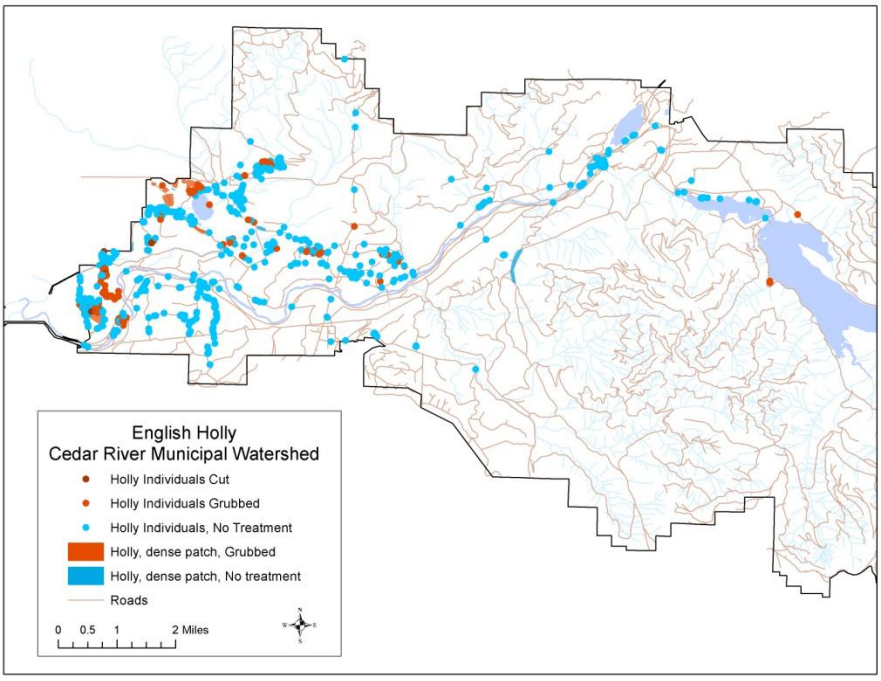
English holly is a shade tolerant small tree that is invading native forests at an alarming rate throughout western Washington. It is the most common invasive tree species in Washington and can form solid thickets, shading out all native understory shrubs and native tree regeneration. Control is not legally required because it is widespread, but is highly recommended in natural areas.

- By 2012 we completed surveys of all areas visible from roads at Lake Youngs. Many scattered individual holly trees were mapped, as well as 14 patches totaling 76 acres of extremely dense holly. In these dense patches holly basically formed a continuous cover in the forest understory (see map), shading out all native understory shrubs and preventing tree regeneration.
- In 2008 and 2009 we began experimental treatment of holly at Lake Youngs as part of a forest habitat restoration project. This consisted of a combination of grubbing out the entire plant, girdling larger trees, and cutting larger trees (a total of 21.1 acres shown in yellow on the map). In addition, because the forest is outside the hydrographic boundary, we also implemented an herbicide treatment (glyphosate) in which we frilled the bark and sprayed a 50% solution of the herbicide directly onto the frill. No herbicide reached the ground during this procedure. Many individuals near the roads (142 individual trees shown in blue or black) and two small dense patches (2.3 acres, shown in green) were treated in this manner.



- In 2011 we monitored the results of the Lake Youngs treatments, documenting amount of mortality. A subsample of 82 trees that had been treated with herbicide in 2008 or 2009 was monitored. Of these, 19 were dead (23%), 11 appeared dead but had some root sprouting (13%), 31 showed damage, but were not dead (38%), 4 showed no damage (5%), and the remaining 17 were not found (21%).
- Holly will be experimentally treated with the cut-stump method (painting the herbicide on the xylem and phloem) using 100% glyphosate with a surfactant as staffing and funding allows.
- In the Cedar we surveyed a small portion of the forest and wetlands in the western portion of the watershed and found many areas with extensive holly, although not as dense as that found at Lake Youngs. There are likely many more patches and isolated plants scattered throughout the Cedar.
- Starting in 2006 and continuing through 2012, we controlled selected holly patches and isolated trees in the Cedar by grubbing out the entire plant or, if it was a large tree, cutting the tree to prevent fruiting.

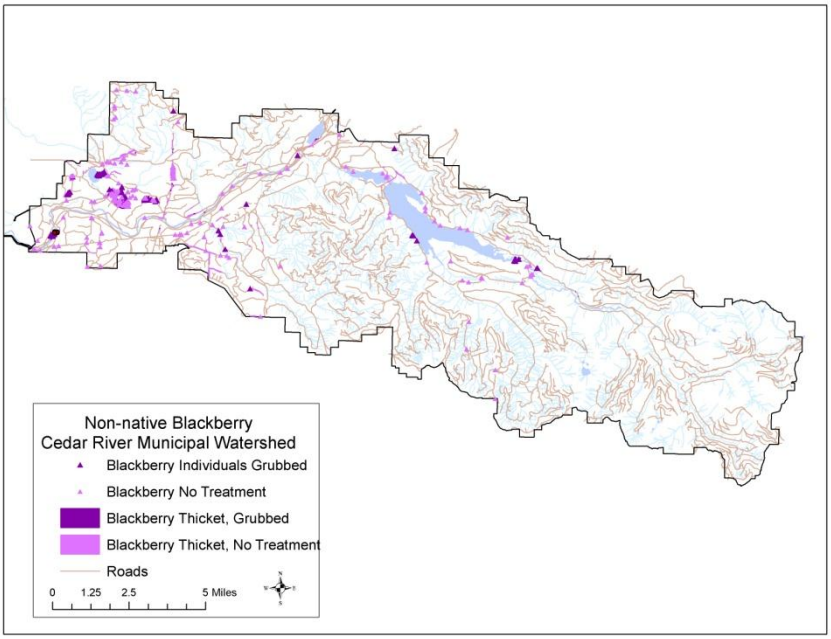
- We focused work in the Cedar in wetlands, high quality forest patches, and forest patches where other restoration projects had either been completed or were ongoing. Total area treated for holly in the Cedar through 2012 encompassed 121 acres.
- We also did an experimental technique, phloem girding, in which the phloem, but not the xylem, was girdled on a few selected larger holly trees near Cedar Falls. After several years there had been no effect on the trees, so this technique was abandoned.
- Although no formal surveys for holly have been conducted at the Tolt, only scattered individuals have been noted. These trees will be controlled and further surveys will be conducted as funding and staffing permit.



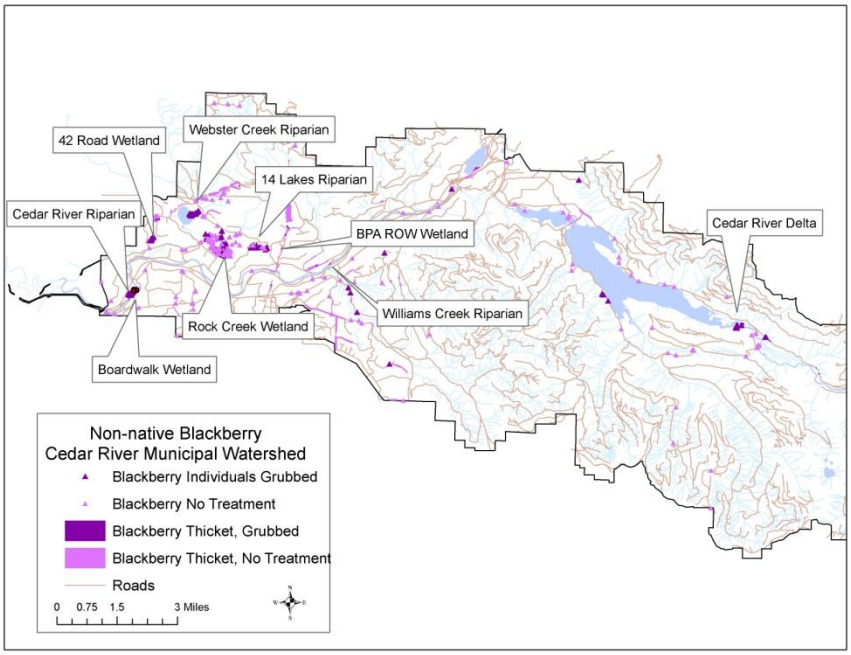
Himalayan and Evergreen (Cutleaf) Blackberry (*Rubus armeniacu, Rubus laciniatus*)

Himalayan and evergreen blackberries are some of the most common invasive species in western Washington. They thrive in a variety of habitats, and often completely take over riparian areas, forest openings, and non-inundated portions of wetlands. They can form impenetrable thickets, with up to 525 canes per square meter, completely disrupting normal ecosystem function. These thickets can produce 7,000 – 13,000 seeds per square meter, with many birds and mammals widely dispersing the seeds. Because these non-native blackberries are so widespread, control is not legally required but is strongly recommended. They are a top priority of the Washington Invasive Species Council.

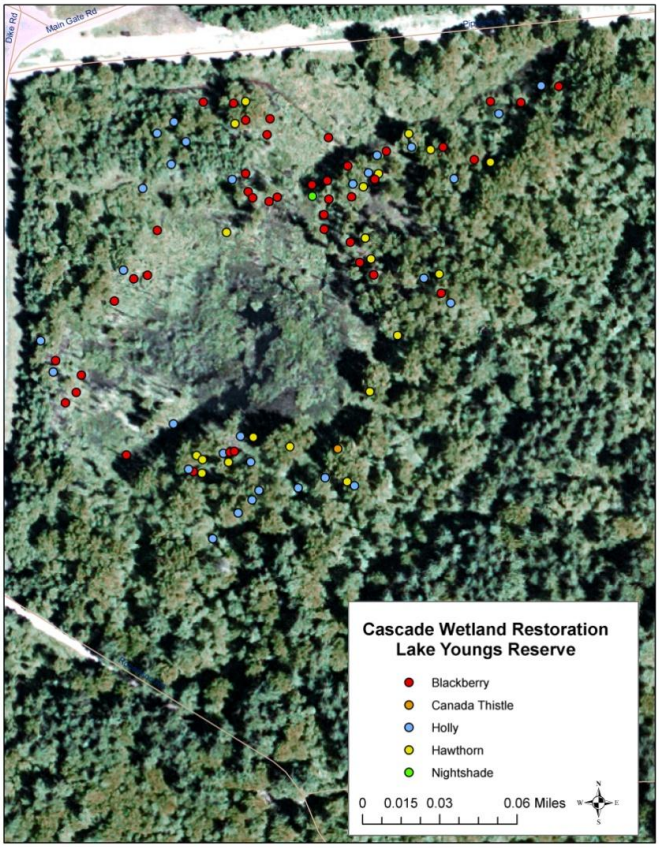
- By 2013 limited surveys for invasive blackberry in the Cedar had been initiated or completed in selected high quality habitats (see map).



- Extensive large thickets of both species were documented in several wetlands and riparian areas around streams, ponds, and lakes in the Cedar.
- From 2005 through 2013 blackberry, along with other invasive species, was hand-grubbed out of seven wetland and riparian areas in the Cedar as part of habitat restoration projects (total of 17.7 acres grubbed, see following map). In order to greatly reduce or eradicate blackberry thickets, all portions of the plant, including roots, must be removed. This generally takes several consecutive years of grubbing because of the difficulty in removing all the roots. There are large amounts of seed present in the soil, so small seedlings must be pulled for several years as well.
- As part of these restoration projects, native shrubs and trees were planted where appropriate, to restore native functioning and compete with the invasive blackberry and other species. Planting was site-specific; where sufficient numbers and variety of native plants were recolonizing naturally, no planting was done.



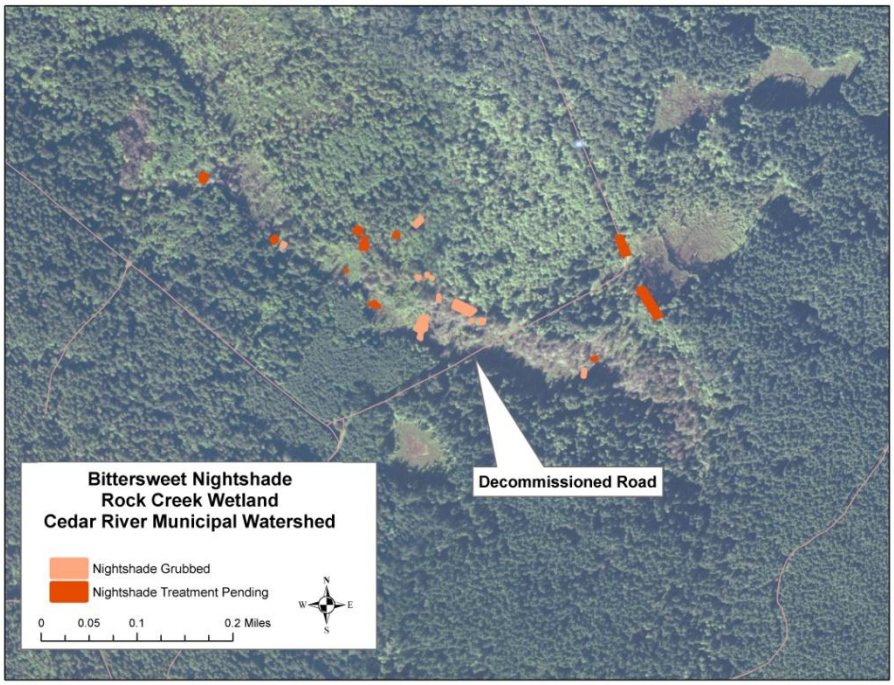
- In 2007 invasive blackberry was mapped in the largest wetland, Cascade Wetland, at Lake Youngs.
- In 2008 and 2009 invasive blackberries, along with several other invasive species, were grubbed out of this wetland (384,621 ft^2 treated, see figure).
- The Cascade wetland will be re-surveyed and evaluated for further restoration work, potentially including more invasive species removal and planting of native species, as funding and staffing allows.
- No surveys for invasive blackberries have been conducted in the Tolt. Surveys will be done in key riparian areas as staffing and funding allow.



Bittersweet Nightshade (*Solanum dulcamara*)

Bittersweet nightshade is a woody vine that can climb 30 or more feet and blanket trees and shrubs. It flourishes in wetlands and riparian areas where it can completely smother native plants, forming immense solid mats of vegetation. It spreads both by the berries and root fragments. Both berries and leaves are poisonous if eaten. Control is not legally required because it is widespread, but control is highly recommended.

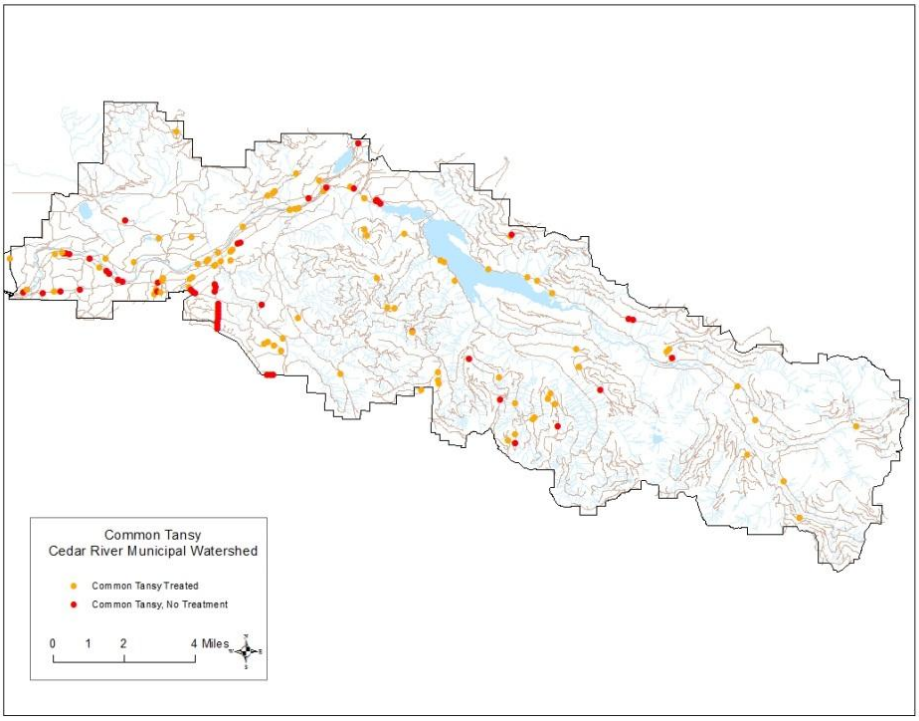
- By 2013 limited surveys in selected high quality wetland and riparian areas in the Cedar were completed.
- Several large patches were documented in Rock Creek Wetland, the largest and highest habitat quality wetland in the Cedar.
- In 2009 we experimentally hand-grubbed an extremely dense patch of nightshade blanketing a beaver dam in Rock Creek Wetland.
- In 2010 we found that the hand grubbing experiment appeared successful, so we grubbed out several more large patches of nightshade (totaling 17,700 ft^2) as part of a Rock Creek Wetland habitat restoration project.
- In 2012 the original patches were starting to re-grow, plus several more large patches of nightshade (>4,000 ft^2) remain in Rock Creek wetland. In 2013 small amounts were re-grubbed. The area will continue to be treated as funding allows.
- Small patches of nightshade in riparian areas along Webster and Rock Creek are controlled when these creeks are surveyed for other reasons.



Common Tansy (*Tanacetum vulgare*)

Common tansy is toxic to humans and animals. It spreads by both seeds and rhizomes, and can form large dense monocultures. It is most often found in disturbed sites. More than 1,000 viable seeds are produced per square meter. Length of seed viability is unknown, but limited data infer it may be short-lived.

- By 2013, extensive surveys were completed in all three watersheds. It was initially found primarily in lower elevations in the Cedar.
- Informal monitoring revealed that it was spreading rapidly in the upper elevations in the Cedar from 2007 to 2012. Consequently, in 2012-13, treatment (digging, covering) was begun on isolated patches and along some major travel corridors so they could not serve as sources for further invasion.

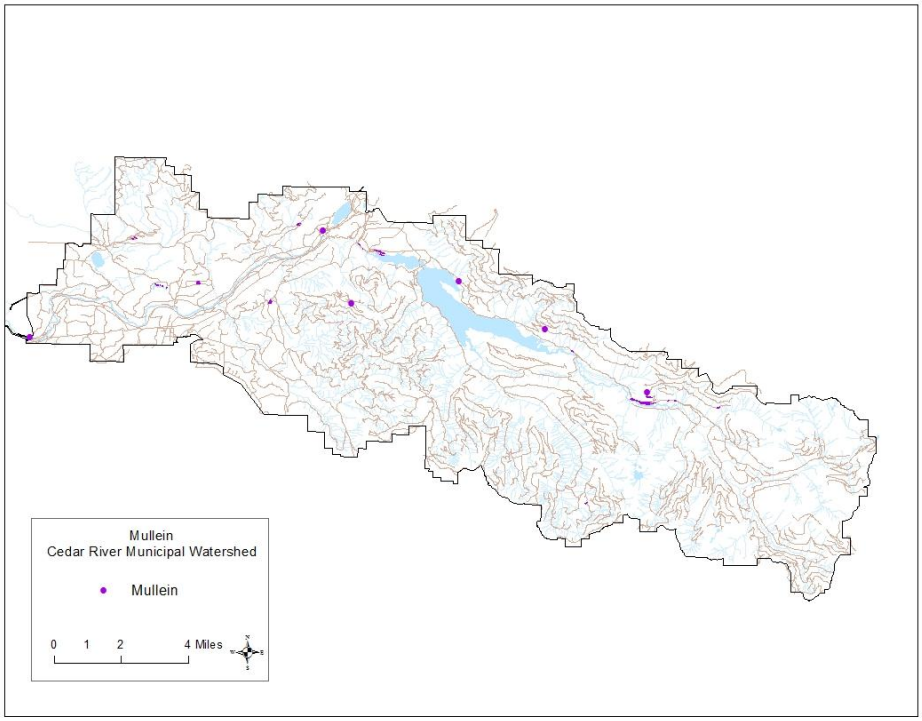


- At Lake Youngs it was found scattered along main roads, in the gravel pit, and in two of the fields undergoing restoration. In 2012 treatment started in all these locations, along with other invasive species. In 2013 only a few scattered plants remained and were treated in all these locations.

Common Mullein (*Verbascum Thapsus)*

Common mullein grows in open, sunny, disturbed sites. It is a biennial, and dies after the flowering stalk produces seed in the second year. A single plant can produce over 100,000 seeds in a year. The seeds can survive almost any conditions, and can remain viable up to 100 years.

- By 2013, extensive surveys were completed in all three watersheds.
- Informal monitoring revealed that it was spreading rapidly in both upper and lower elevations in the Cedar. Consequently, in 2013, treatment (digging) was begun on isolated patches, in gravel pits, in restoration project sites, and along some major travel corridors so they could not serve as sources for further invasion.



LOW MANAGEMENT PRIORITY – LOWER CURRENT ECOLOGICAL THREAT, WIDESPREAD

The other non-native invasive plant species listed in Table 1 have been documented in Seattle's major watersheds, but are not yet completely mapped and are not legally required for control. A few (e.g., sycamore maple, black locust) are being controlled in certain sites as part of habitat restoration projects or projects in gravel pits to help minimize spread of invasive plants to other areas. Others (e.g., Saint Johns-wort) are part of biocontrol experiments.

Appendix 2. Aquatic Nuisance Species that could potentially invade the watersheds

Scientific Name	Common Name	Species Type	Habitat Type
Plants			
Cabomba caroliniana	Carolina fanwort	Aquatic submerged & emergent rooted plant	Lakes, ditches, canals
Callitriche stagnalus	Pond water-starwort	Aquatic rooted plant	Shallow water, lake edges
Egeria densa	Brazilian waterweed	Aquatic submersed rooted plant	Lakes
Eichhornia crassipes	Water hyacinth	Aquatic floating plant	Lakes
Hydrilla verticillata	Hydrilla	Aquatic, submersed rooted plant	Lakes
Myriophyllum aquaticum	Parrot feather	Aquatic rooted plant	Slow moving nutrient rich water
Myriophyllum spicatum	Eurasian milfoil	Aquatic submersed rooted	Lakes
Nymphaea odorata	White water lily	Aquatic rooted plant	Shallow lakes
Nymphoides peltata	Yellow floating heart	Aquatic rooted plant	Shallow lakes
Potamogeton crispus	Curly pondweed	Aquatic rooted plant	Shallow lakes
Sagittaria graminea	Grassy arrowhead	Aquatic rooted plant	Shallow lakes
Utricularia inflata	Swollen bladderwort	Aquatic submersed, free-floating plant	Shallow waters
Animals			
Argulus japonicus	Parasitc copepod	Invertebrate	Transported by fish
Carassius auratus	Goldfish	Fish	Freshwater ponds, lakes
Corbicula fluminea	Asian clam	Invertebrate	Wide range of lakes and streams
Cordylophora caspia	Freshwater hydroid	Invertebrate	Lake bottoms

Craspedacusta sowerbyi	Freshwater jellyfish	Invertebrate	Range of freshwater habitats. Blooms in warm water
Cyprinus carpio	Carp	Fish	Freshwater lakes, wetlands.
Dreissena polymorpha	Zebra mussel	Invertebrate	Wide range of lakes and rivers
Dreissena rostriformis bugensis	Quagga mussel	Invertebrate	Wide range of lakes and rivers
Eriocheir sinensis	Chinese mitten crab	Invertebrate	Lives in fresh water, but breeds in brackish water
Misgurnus anguillicaudatus	Oriental weatherfish	Fish	Freshwater lakes, wetlands; survives in cool water.
Myocastor coypus	Nutria	Mammal	Wetlands, riparian
Pectinatella magnifica	Magnificent bryozoan	Invertebrate	Warm freshwater lakes and rivers
Potamopyrgus antipodarum	New Zealand mud snail	Invertebrate	Wide range of lakes and streams
Diatoms and Algae			
Didymosphenia geminata[1]	Didymo	Diatom	Lakes, Streams
Parasites			
Myxobolus cerebralis[2]	Whirling disease	Myxosporean parasite	Parasite on salmonids

[1]Native species already present in Cedar. Fairly ubiquitous in Cedar River downstream of Masonry Dam. Can cause nuisance blooms, especially in regulated flow situations.

[2]Causes whirling disease in salmonids. Requires a segmented aquatic worm to complete its life cycle.

Appendix 3. Insects and pathogens that could invade or have outbreaks in watershed forests

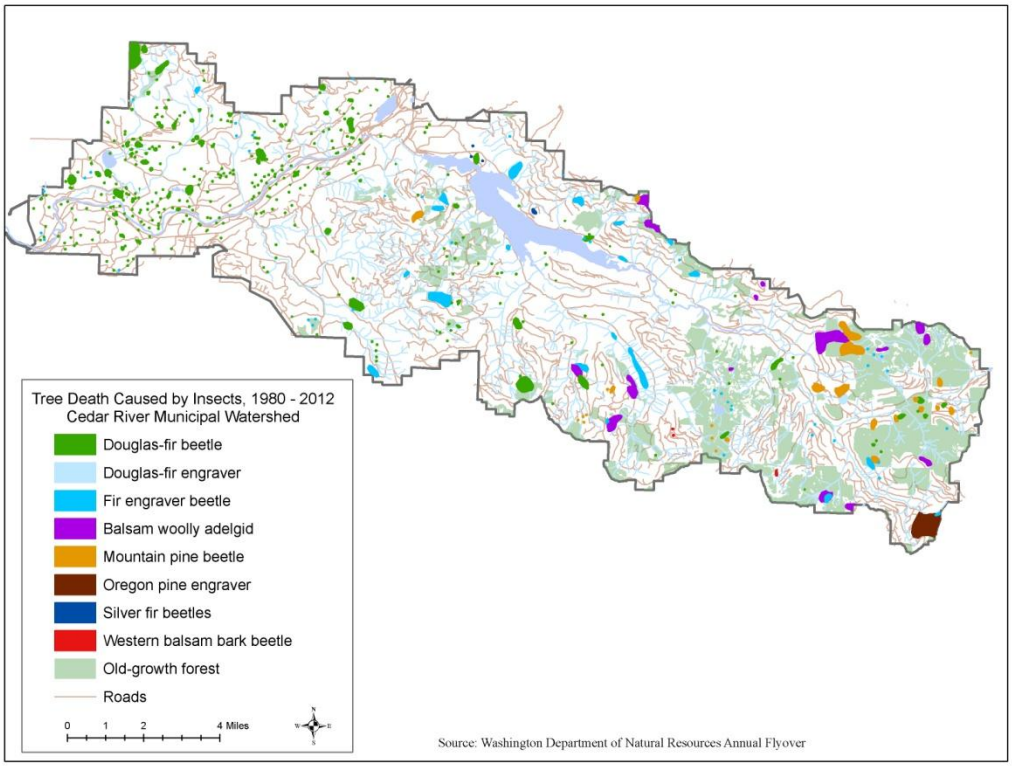
Scientific Name	Common Name	Tree species most susceptible	Action	Notes
Non-native species posing significant risk				
Adelges piceae	Balsam woolly adelgid	True firs (*Abies spp*) especially Pacific silver fir, subalpine fir, and possibly grand fir	Sucking insect	Can stunt terminal growth or infest entire bole, killing tree. Currently present in Cedar.
Anoplophora glabripennis	Asian longhorn beetle	Broadleaf trees (bigleaf maple, black cottonwood, willow)	Bark tunneling	
Cronartium ribicola	White pine blister rust	Western white pine	Kills young and pole size trees, forming cankers on main stem.	Has almost eliminated western white pine from forests
Elatobium abietinum	Green spruce aphid	Sitka spruce	Sucking insect	Can defoliate trees
Lymantria dispar	European or Asian Gypsy moth	Asian: Conifer and deciduous trees; European: Deciduous trees.	Defoliator	
Monsoma pulveratum	Green alder sawfly	Red alder	Defoliator	Can defoliate trees in riparian areas
Phytophthora ramorum	Sudden oak death	Conifer and deciduous trees, many shrubs	Attacks leaves	Rarely found outside nurseries, but can escape into natural areas
Native species that that could potentially have severe outbreaks under changed circumstances				
Acleris gloverana	Western blackheaded budworm	Western hemlock, Pacific silver fir	Terminal bud damage or death	Currently present in Cedar
Armillaria spp	Armillaria root disease	Conifer and deciduous tress	Root and butt decay	Generally only kills trees already under stress
Choristoneura occidentalis	Western spruce budworm	Douglas-fir	Defoliator	One outbreak recorded in western WA but primarily on the east side.

Dendroctonus ponderosae	Pine bark beetle or mountain pine beetle	Western white pine	Attack under the bark	Infestation usually always results in tree death.
Dendroctonus pseudotsugae	Douglas-fir beetle	Douglas-fir	Attack under the bark	Current monitoring program in localized portion of the Cedar
Heterobasidion annosum	Annosum root disease	Most conifer trees in Washington	Root and butt decay	Normally kills only small pockets of trees, but widespread in portions of the Cedar
Ips pini	Oregon pine engraver beetle	All pine species	Attack under the bark	
Lambdina fiscellaria lugubrosa	Western hemlock looper	Western hemlock	Defoliator	Outbreaks linked with drought cycles
Phaeocrytopus gaeumannii	Swiss needle cast	Douglas-fir	Needle death	Currently causes little death, but can stress the tree.
Phellinus spp	Laminated root rot	Douglas-fir	Root rot	Normally kills only small pockets of trees, but widespread in portions of the Cedar
Pissodes strobi	Sitka spruce weevil	Sitka spruce	Kills leader	Attacks seedlings and saplings, especially planted stock
Scolytus ventralis	Fir engraver beetle	True firs, Douglas-fir	Attack under the bark	Can have major outbreaks under prolonged drought

Appendix 4. Locations of tree death in the Cedar by causal agent.

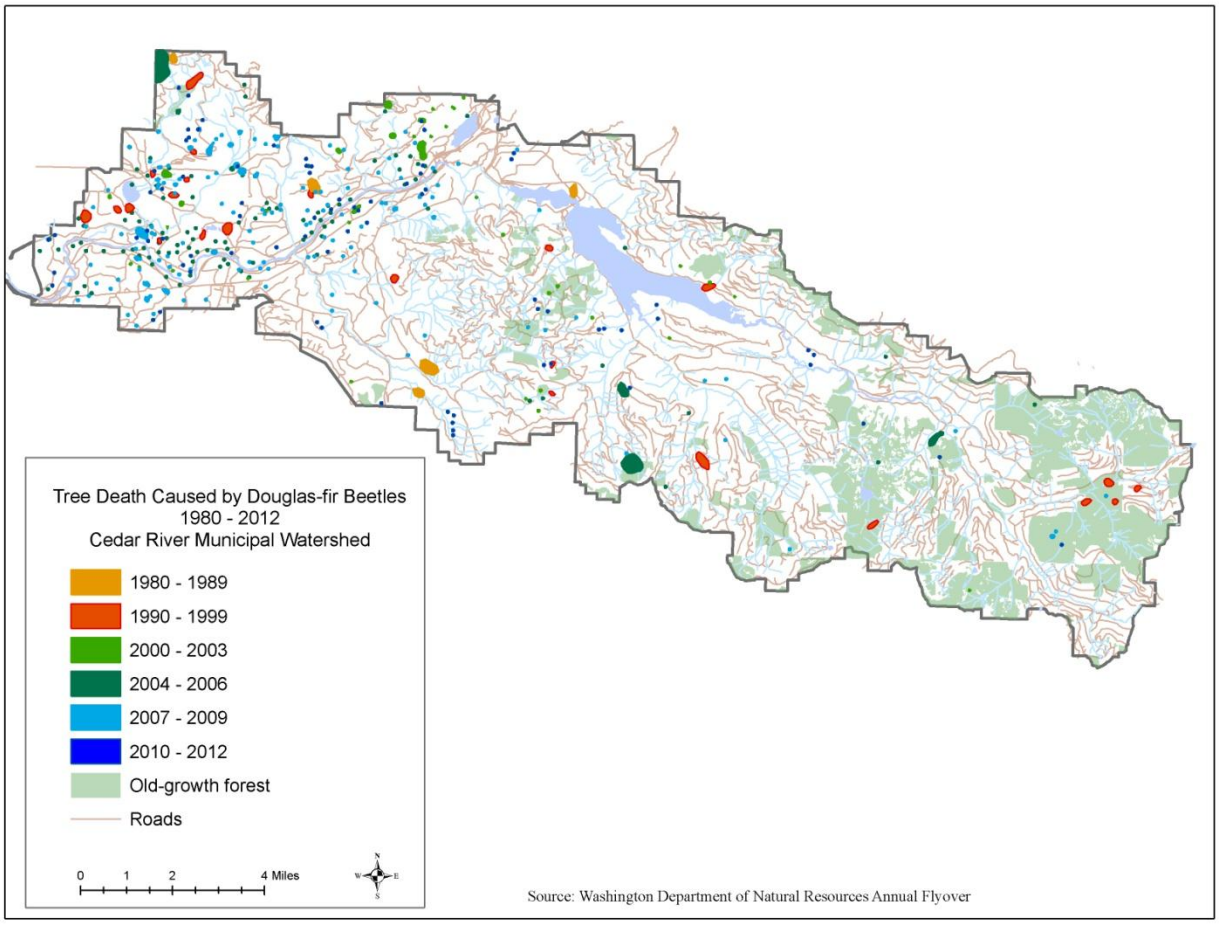
Each year, all forested federal, state, and private land in Oregon and Washington are aerially surveyed for insect and disease damage. This survey is flown cooperatively by the Forest Insects and Diseases group of Region 6 US Forest Service; the Insect and Disease Section of the Oregon Department of Forestry; and the Washington Department of Natural Resources. These data are collected to determine regional insect and disease trends and to serve as an indicator to land owners/managers on insect and disease activity in their area. The causal agents of the tree mortality are predicted based on the type and pattern of defoliation seen. However, these predictions are only an indicator of insect or disease activity and should be ground verified. All data are collated in GIS, posted on the internet, and available for public use.

The GIS polygons indicate areas of tree mortality or defoliation; intensity of damage is variable and not all trees within the polygons are affected. The primary agent of mortality in the Cedar from 1980 through 2012 was Douglas-fir beetle (see data for all years combined in the map below). The fir engraver beetle, balsam wooly adelgid, mountain pine beetle, silver fir beetle, and western balsam bark beetle have sporadically caused small pockets of mortality. The relatively large brown polygon in the southeastern corner of the watershed with mortality attributed to the Oregon pine engraver beetle occurred in 2003, with no further occurrences recorded. This site was not field verified, and there is very little pine in the watershed, so this data point may have been misclassified.



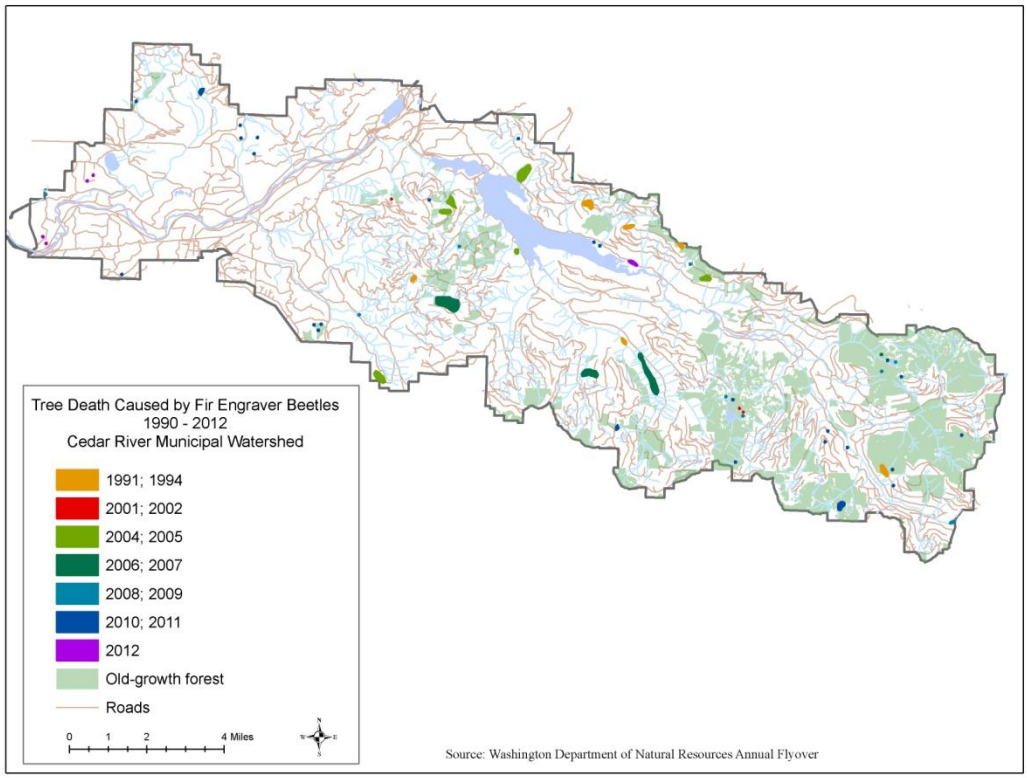
Douglas-fir Beetle

The Douglas-fir beetle is a native insect that generally causes small pockets of Douglas-fir tree mortality. In late 2003 there was a large wind storm that caused several areas of windthrow in the Cedar, and another windstorm in 2007 that caused large amounts of windthrow throughout King County. The windthrown trees provided good substrate for the beetles, whose populations then increased for the next several years leading to the highest levels of Douglas-fir beetle caused mortality in western Washington in 30 years. The map shows that the majority of tree death in the Cedar from the beetles occurred from 2004-2009, with far less in 2010 - 2012. The mortality was concentrated in the lower elevation western portion of the watershed, which is dominated by relatively dense stands of Douglas-fir. The relatively widespread but small pockets of mortality created small snag patches that benefit numerous snag dependent species, as well as creating structural diversity in the forest. These data will continue to be monitored to see if these patterns change through time.



Fir Engraver Beetle

The fir engraver beetle is another native species that generally feeds on true firs (*Abies sp*), but can also attack Douglas-fir. Areas of mortality have been scattered in the higher elevation forest in the eastern portion of the watershed, with more recent mortality (2010-11) seen in or near old-growth forests. To date, patches of mortality have been generally small, with the largest patches recorded in 2006-07. They will be ground verified if future data show cause for concern.



Balsam Woolly Adelgid

The balsam woolly adelgid is a species of concern because it is non-native and has not evolved in these forests, thus poses a significant threat. There were several patches of tree mortality attributed to this species in the 1990s, but only a few scattered patches in the 2000s, with the most recent two small patches documented in 2009. There was an attempt to field verify these patches in 2010 and 2011, but no tree mortality or evidence of balsam woolly adelgid was found at either location.